

FOOD INDUSTRY



VOLUME 17
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PUBLICATION OF ASSOCIATION OF FOOD SCIENTISTS AND TECHNOLOGISTS (INDIA)

EMULSION STABILITY
IN FOOD PRODUCTS

Fat Replacers

Bioproduction of Food
Flavours

Nutritive Sweeteners



ASSOCIATION OF FOOD SCIENTISTS AND TECHNOLOGISTS (INDIA), MYSORE - 570 013

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- Affiliated to the Institute of Food Technologists, Chicago, Illinois, U.S.A.
- The Association is a professional and educational organization of Food Scientists and Technologists, with its headquarters at Mysore.
- The Chapters of the Association are located at Bangalore, Bhopal, Calcutta, Chennai, Delhi, Hisar, Hyderabad, Jabalpur, Jaipur, Jammu, Kanpur, Karnal, Kharagpur, Ludhiana, Manipur, Mumbai, Nagpur, Pantnagar, Parbhani, Pune, Thrissur, and Thiruvananthapuram,

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- Advancement of all the aspects of Science and Technology relating to Production, Processing and distribution of food, with the ultimate objective to serve humanity through better food.
- Promotion of research, development and training in the Science, Technology and Engineering of Food.
- To provide a forum for exchange, discussion and dissemination of knowledge and current developments, especially among Food Scientists and Technologists as well as the Public and Society at large.

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- Publication of 'Journal of Food Science and Technology' (bi-monthly) and 'Indian Food Industry' (bi-monthly).
- Holding symposia/conventions on different aspects of Food Science, Technology and Engineering.
- Arranging Lectures and Seminars for the benefit of Members and the Public.

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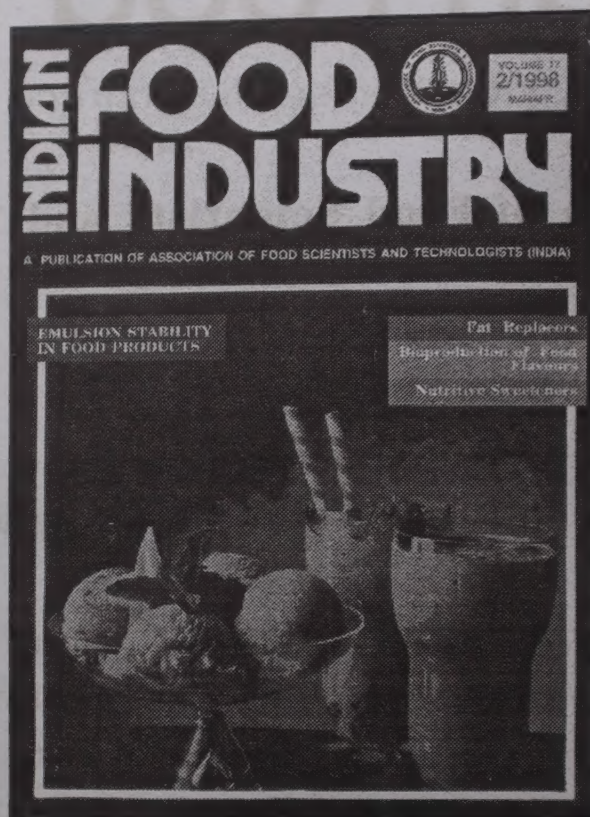
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Review articles, technology papers based on R&D work and reports on various aspects concerning food industry are welcome from food scientists and technologists from industry, research institutions and other related organisations. Contributors are advised to provide good quality illustrations in the form of charts and photographs along with the manuscripts. The Editorial Board reserves the right to edit the manuscripts in order to make them suitable for publication in the journal, while assuming no responsibility for the statements and opinions expressed by the contributors, nor will they bind AFST(I) in any way. Readers are free to air their views through letters which may be published in the journal from time to time.

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FROM THE CHIEF EDITOR'S DESK

It is difficult to figure how, in Indian parlance, 'fat' or 'fatness' is associated with arrogance and snobbery. • Could it be that fat in the wrong places of the body imparts grotesqueness, which the person can take advantage of, to feign superiority over the lean and timid-looking ones ? I have often admired with some distaste though, but with much anxiety, the mountainous Sumo wrestlers in action, lest their brief loin cloth should give way. But then, it used to occur to me that the bout has very little technique, but much of mass action - mass against mass. Indeed, fat in the right places and in right quantities is a lot good, for it provides cushioning protection to the organs and proper body contours, besides being vitally important as storage energy, vitamin repository and contributing to cell membrane integrity. In the wrong places and in excess of what is normal, fat assumes the roguish role in aggravating coronary heart disease, diabetes, hypertension etc. Dietary habits may have some role, not all, in determining whether body fat is a boon or bane. There certainly is a genetic factor in abnormal accumulation of fat. In any case, there is a lot to gain in diet control, evident from the voluminous data already obtained. For those, who "want to have the cake and eat it too", the make-believe and taste-alike fat is now on the horizon, in the form of fat replacers and fat analogues (pp 89 - 97 in this issue).

The eminent nutritionist Dr. K. T. Achaya has opined that cereals, pulses, vegetables, and fruits naturally contain adequate fat that is good enough to meet the dietary requirement and there is no need for extraneous addition of oil to food. Since fats and oils are integral to the culinary practice all over the world, the fat replacers and oil analogues should be wholeheartedly welcome for adoption by the food industry.

Richard Joseph

Quantitative Restrictions on Agricultural Products

The Agriculture ministry has finalised the critical phase out plan for quantitative restrictions (QRs) on agricultural products based on the domestic production of the item.

A report on QRs for imports of agricultural and agricultural products states that the time frame would be two years for 233 items, 10 items in 3 years, 38 in 5 years and 178 within 8 years. Some 42 items like cereals constituting the staple diet of Indians, will be kept for the end.

The phase-out schedule would probably be revised to accommodate all commodities within the six-year phase-out plan that India has since agreed to follow. India has proposed a three-tier phase-out on three, two and one year beginning April 1, 1997. The report of the committee appointed to look in to the QRs issue for agricultural products states that under Article 19 of the GATT 1994, there are provisions and requirements to levy safeguard duties or import restrictions similar to those in case of levy of antidumping duty.

India's reluctance to accept removal of QRs on agricultural commodities is based on the heavy dependence of the agri-economy on the monsoon, small holdings and other variable factors. The developed countries had asked for at least 60 per cent of QRs to be removed in the first three years. But, agricultural products are heavily subsidised in most

developed countries and so, their prices are more competitive.

Government Allows Exports of Pulses in Consumer Packs

Prices of pulses have recorded a sudden rise as the government has opened up exports in 5 kg consumer packs. The Pulses Importers Association (PIA) has urged the government to withdraw this notification as early as possible.

This follows a notification issued by the Director-general foreign trade (DGFT) on December 1, 1997 removing pulses exports from restricted list. The notification permitted exports of pulses (lentils, grams, beans and flours made therefrom) in consumer packs of 5 kgs.

In a letter written to the Union ministries of commerce and food and agriculture, PIA has mentioned that the untimely notification has resulted in sharp rise in the prices of pulses. The prices of pulses in Mumbai have shot up by Rs 200 to Rs 250 per quintal.

According to PIA, before the notification, gram which was quoted at Rs 1500-1800 per quintal shot up to Rs 1725-2000, gram dhal was up from Rs 1650-2050 to Rs 1800-2200 and moong was up from 1500-2400 to Rs 1750-2800 per quintal.

Similarly, turdhal was up from 1500-2600 to Rs 1650-2750, blackgram moved up from 1500-2000 to Rs 1650-2150 and masur dhal also moved up from Rs 1600-1900 to Rs 1750-2050.

Oilmeal Exports Decline During 1997-98

Oilmeal export may decline substantially in the current year. As against the projected exports of 4.6 million tonnes valued at Rs 3,086 crores during 1997-98, the actual exports during April 1997-January 1998 have touched only 3.4 million tonnes, valued at Rs 2,355 crores.

During 1997-98, exports were expected to touch 4.3 million tonnes valued at Rs 2,926 crores as against the 4.3 million tonnes valued at Rs 3,156 crores recorded in 1996-97.

Decline in exports is mainly attributed to fall in international prices by 20-30 per cent in the last six months. The devaluation of currencies of many south Asian countries has seriously affected exports. Many of these countries account for nearly 60 per cent of deoiled meal exports from India.

Raw material shortage for processing and excessive imports of edible oils have made the domestic processing industry unviable. Many units have been closed or are on the verge of closure. The units are currently operating at very low capacity utilisation. A hike in freight has forced units located in hinterlands to sell their produce locally, as export of deoiled meal has become unremunerative.

The industry has suggested that the rupee should be allowed to fluctuate without intervention. If the rate of Rs 42 a dollar is achieved, it will boost export. The industry feels that import of rice

bran and oilseeds would boost processing and exports. The ministry of agriculture has indicated that it has no objections on imposing a quarantine ground for import of these commodities. The ministry of commerce was requested to consider this option and allow import of these commodities with immediate effect.

Palm Oil Consumption Picking Up in Kerala

With an increasing number of coconut oil producers diversifying to palm oil, a small pack revolution is slowly getting underway in the branded palm oil market in Kerala.

After the small pack revolution in the branded coconut oil market segment, it is now the turn of the branded palm oil in small packs. Some of the traditional coconut oil producers have already launched small packs of palm oil of 1 litre and half litre.

Several other traditional coconut oil manufacturers are also preparing to launch palm oil in small packs. Two to three other companies are expected to launch their products soon.

A high degree of competition in the branded coconut oil segment and a gradually increasing preference for palm oil in the market are the main factors that have resulted in the rise in the branded palm oil segment.

The imported palm oil is available at a price of Rs 28 per litre. Total costs for a small pouch manufacturer would be around Rs 32 per litre. There is also a growing demand for palm oil in the important markets. For example, in Kerala, the palm oil is making a come back as a cooking oil. It was widely in use in the early 1980s as

an edible oil. Though subsequently its demand fell, the palm oil is now making a come back, thanks to imports from Malaysia.

Export of Campco's Arecanut Leaf-cup Soon

The Mangalore-based Central Arecanut and Cocoa Marketing and Processing Cooperative Ltd (Campco)'s proposed arecanut leaf-cup export project is expected to be launched soon.

Campco had planned to manufacture and export eco-friendly bio-degradable arecanut leaf products in the form of cups and plates to Singapore about a year ago and had signed a tripartite agreement with Central Food Technological Research Institute (CFTRI), Mysore and a Singapore-based firm, Next Paradigm Concepts Private Ltd (NPCPL).

CFTRI has started working on the machine to suit the international standards. The fabrication work has reached advanced stages of completion and it is likely to be ready in two months' time.

Arecanut leaf is widely used for various purposes by the farmers in arecanut growing areas and it can be an alternative for plastic, because it gets degraded with the soil. In the western ghat districts, the farmers use arecanut leaf for making hats to get protection from heavy rains. Campco would be the first firm to make use of arecanut leaf for commercial purposes. It plans to initially market the product in Singapore through NPCPL and later in other South-east Asian countries.

Some Real Facts about Cereals Output

World cereal production (including paddy) in 1997-98 has been revised upward to nearly 2,090 million tonnes from the initial forecast of 2,075 million tonnes; the increase is by 0.6 per cent over the anticipated output of 2,077 million tonnes in 1996-97.

In terms of rice milled equivalent, the total global cereals production is expected at 1,901 million tonnes, up by 0.6 per cent over the 1996-97 level and by about 13 million tonnes more than the initial forecast of 1,888 million tonnes for the current year.

In spite of the estimated higher production for 1997-98, the "global carry-overs are forecast to remain below the minimum safe levels," according to FAO.

In the event of a set back in food outlook for 1998-99, the world cereals position will correspondingly deteriorate, leading to a possible flare up in grain prices.

The revised higher cereals output in 1997-98 is largely on account of upward revision in wheat production at 611 million tonnes as compared with the previous forecast of 592 million tonnes.

Over the latest output estimate of 592 million tonnes for 1996-97, the higher wheat production forecast for 1997-98 will be up by 3.2 per cent.

Initially, Indian wheat output as forecast was promising. A target of 68 to 69 million tonnes was set. But with the not-so-favourable weather conditions during November-December 1997, wheat production has now been scaled down to 63 - 64 million tonnes; and in 1996-97, the country harvested nearly 68 million tonnes.

In respect of coarse grains, available indications are that though the revised production es-

timates are likely to be on the higher side, the quantum will still be less than 1996-97 level.

In 1996-97, coarse grains production had leaped to a record 917 million tonnes from an estimated 816 million tonnes in 1995-96. The setback during 1997-98 compared to 1996-97 will be largely due to an expected 10 per cent fall in output in the Asian region.

The region is, however, unlikely to show any market step up on account of unfavourable weather conditions in some Asian countries. Though world cereals outlook for 1997-98 has decidedly turned better, this should not induce complacency as many countries are facing tight food conditions.

From the global food security point of view, one more promising harvest in the coming 1998-99 season is being felt necessary. Otherwise, food security of several low-income countries, especially those of the African region, would come under severe pressure.

SPIC Floats Joint Venture with Technipetrol of Italy

The Fertiliser major, SPIC, has floated a joint venture with Technipetrol of Italy, a world leader in engineering contracting, for providing engineering services to a host of industries.

Mr A.C. Muthiah, Vice Chairman and President of SPIC, and Mr M Glordano, Director of Technipetrol, signed an operating agreement in Chennai recently in the presence of Italian Prime Minister Prof Romano Prodi and the Chief minister of Tamil Nadu, Mr M Karunanidhi.

The joint venture, Technipetrol India Ltd, will have an authorised capital of Rs 10 crores and paid-up capital of \$1.4 millions with the two partners taking up a stake of 50 per cent each.

It is proposed to have a strength of five lakh engineering manhours per annum (1,700 man-hours for one person).

The services would be offered to refinery, petrochemical, chemical, fertilisers, power, environmental and pharmaceutical industries in India, South-east Asia, Middle East and Central Asian Republic.

With globalisation of the Indian economy, SPIC perceived a tremendous potential for the service sector in the next few decades.

Nirma Enters Kitchen Shelves in the Form of Salt

The Ahmedabad-based Nirma Ltd is now gearing itself for a new venture for entry into the packaged foods market.

In fact, the company has already begun test marketing its first product, vacuum salt in Ahmedabad. The product, under the brand name Nirma, is priced at Rs 5 for a one kilo pack and will be rolled out nationally shortly. Salt is only the stepping stone for the company's entry into the packaged foods market. Once the consumer acceptance for salt is fairly well established, it plans to move into other categories such as *atta* and spices.

Apart from salt, the company is also contemplating entering the coffee market, sometime in the future.

Although the company is still working on the nitty-gritties of the new business development,

salt sales alone will bring the group an additional turnover of about Rs 150 crores, if the venture is successful. The fact is that the company will not have to make any huge investment for the salt business, since it is a by-product of soda ash, makes the prospect more attractive. Nirma's soda ash plant goes on stream early next year.

Cardamom Output May Go up by 15% This Season

India's cardamom production is likely to increase by 15 per cent this season (August 97-July 98), despite sharp fall in the commodity's prices during the last two years.

Cardamom production is likely to be 7,650 tonnes this season against 6,625 tonnes last year, according to a Spices Board official. This season's production is expected to be better than that during 1995-96, when India produced 7,500 tonnes.

Last season's production, on the other hand, was only slightly more than the 6,000 tonnes produced during 1993-94. Production for 1996-97 was lower than initial estimates of 6,750 tonnes.

Cardamom production in India has been erratic during the last couple of years mainly in view of the growers realising lower prices.

Prices of the commodity have crashed mainly due to sagging exports, which have been hit by the stiff competition being offered by the tiny Central American country Guatemala. The rise in this season's production of cardamom is being viewed as efforts on the part of the growers to increase productivity, which is seen as the only solution to lower prices. The Spices Board has tar-

geted a production of about 10,000 tonnes for cardamom by the end of the Ninth Plan.

As part of its efforts to promote domestic consumption, the Spices Board has spread its auction base to Mumbai and Delhi this year.

Wheat Output May Decline by 2.5 Million Tonnes

A decline in the area under wheat cultivation by about one million hectare from last year's 26 million hectare is causing concern in the Agriculture ministry.

This will result in a decline by about 2.5 million tonnes in wheat production, which agro-economists estimated at 69.3 million tonnes for 1997-98.

The calculation is based on the assumption that the average productivity of wheat is 2.6 tonnes per hectare. Incessant rains in November and December, 1997 and late-sowing in a lot of areas has led to damage of wheat crop.

Last year, the total wheat production touched a record 68.5 million tonnes and foodgrain production was 198 million tonnes. This year, the agriculture ministry has estimated total foodgrain production at 200 million tonnes despite projections by the Planning Commission of 202 million tonnes.

Wheat production invariably sets the trend for total foodgrain production. So, a good wheat year implies high foodgrain production.

In August last year, the Government had authorised the Food Corporation of India and the State Trading Corporation to import upto 2 million tonnes of wheat during 1997-98 to augment stocks.

Government Allows Exports of Wheat Products

The Government has approved removal of quantitative restrictions on exports of milk and oilseeds and allowed wheat product exports as part of the efforts to boost agricultural trade in the current fiscal year.

Official sources revealed that the Government had however, fixed a ceiling of five lakh tonnes for export of wheat products, which should be in consumer packs.

Concerned over the sagging exports, the Commerce ministry was keen on giving a fillip to Agro exports and only recently gave clearance for exports of pulses in consumer packs.

Removal of quantitative restrictions of milk exports comprised baby milk and sterilised liquid milk, while oilseeds included groundnuts, sesame seeds, niger seeds and castor seeds.

Besides, the air freight subsidy scheme on selected horticulture and floriculture products and vegetables would be continued upto March this year to cover the full year.

Also, the air freight subsidy scheme had recently been approved for exporting one-day-old chicks and eggs for hatching purposes.

Special efforts to develop protocol for export of mangoes to Japan, Australia and New Zealand were on with the setting up of cargo handling facility for perishable commodities at the Indira Gandhi International airport in the Capital.

Certification Scheme for Food Products

In order to enhance the export prospects of Indian food products, which have been facing non-tariff barriers of this kind, the Bureau of Indian Standards (BIS) has launched an exclusive certification scheme. Called the Hazard Analysis Critical Control Points (HACCP) certification based on IS 15000 : 1998, it meets all international requirements as laid down in the Codex Alimentarius Commissions Standard' 97.

The certifications scheme has been introduced in the backdrop of major food importing nations like Australia, New Zealand, Canada and the U.S. according to mandatory status and fixing deadlines for certification under the HACCP scheme for products like meat, poultry, marine products, fruits and vegetables and processed foods.

The HACCP scheme is intended to act as a complement to the ISO 9000 quality system standards. Certification under these two schemes can be taken simultaneously through quality audits. Units taking certification in HACCP scheme can derive important benefits like reduction of contamination, production, destruction and preferred supplier status.

Asian Currency Crisis Hits Indian Rice Exports

India's rice exports have hit a rough patch due to the drop in Asian currencies, but exports for the whole of 1997-98 (April -

March) should be steady at around 1.7 million tonnes.

Mr Anil Adlakha, Executive Director of the All India Rice Exporters' Association, told that given a good monsoon, India should export about 2 to 2.2 million tonnes of rice, including over 450,000 tonnes of aromatic Basmati, in 1998-99.

In 1998-99, if monsoons again behave favourably higher world demand is anticipated because of the effect of El Nino, especially in Indonesia, the Philippines and Brazil, where demand will be high.

World rice demand is projected at 17.8 million tonnes in 1997 compared with 19.4 millions in 1996. Trade sources forecast that 1998 demand could rise by one million tonnes due to the effects of the EL Nino weather phenomenon.

India is battling to remain internationally competitive as prices of rice from Thailand, Vietnam and Pakistan have become cheaper due to the devaluation of their currencies.

Its impact had been felt on the Indian currency, whose value against the dollar has also come down by about 8 to 10% of late. Before the devaluation, rice from Thailand-the world's largest exporter-cost \$25 to \$30 per tonne more than Indian rice of similar origin.

Exporters would be happy if the Indian rupee stabilised around 41 to 42 rupees per dollar. It was trading around 39.25. Rice exports have seen sharp fluctuations in the last three years, from some 89,000 tonnes in 1994-95 to 5.51 million tonnes in 1995-96 and 2.47 million in 1996-97.

The Government must initiate a long-term policy on rice exports for India to remain a global player.

Growth Stunted in Soft Drinks Sector

Consumption of soft drinks does not seem to be picking up as expected. The growth in the industry has been on the decline. The Rs 1,800-crore plus industry has recorded a dismal 8 to 10 per cent growth last year. The year before last, the market grew about 12 per cent, according to industry sources. 1995-96 saw the highest growth rate of about 20 per cent.

Among the big players, Pepsi Food claims to have registered the highest growth of about 20 per cent. According to a company spokesperson, it has also been able to garner an additional share points of two to reach 43 per cent market share.

Coca-Cola India, on the other hand, has grown only 5 per cent, according to figures published by its parent company in Atlanta. The last quarter, though, has been fairly good for the company having registered an 8 per cent growth. Coca-Cola India has a 51 per cent share in the market.

The other player in the country Cadbury Schweppes, with a market share of about 4 per cent has not seen any significant growth.

The cans, though, have grown to contribute about 2 per cent of the total sales, having moved up from the less than one per cent in 1996. The price reduction from Rs 18 to Rs 13 has been the catalyst, said analysts. The 1.5 litre PET bottles have also fared well.

Tamil Nadu Promises Support to Develop Food Sector

The Tamil Nadu government has called upon the international food processing chains to set up a base in Tamil Nadu and utilise the agro-horticultural opportunities available in the State.

The State Chief Minister, Mr M. Karunanidhi said that the international food chains could take advantage of the favourable policy environment, food production and processing climate prevailing in the State for their investments, while inaugurating Food Pro'97, an international conference and exhibition on the food processing sector, organised by the Confederation of Indian Industry (CII).

He assured his government's support for the development of food processing sector in the State.

He said that the State recently conducted a study on 'Changing structure of demand for agricultural products in Tamil Nadu' through Tata Economic Consultancy Services, which has predicted the demand in 2001 for foodgrains, sugar, edible oils, fruits, vegetables, milk, meat and eggs.

Mr M. Karunanidhi said that the upcoming agro processing parks in Nilakottai and Ambattur and the horticulture park at Hosur with an horticulture auction centre in Chennai will provide the much needed infrastructure for promoting exports of processed food products from Tamil Nadu.

Mr Karunanidhi said that the food processing sector in Tamil Nadu has been dominated by about 34 thousand small and cottage industries in the unorganised sector. Nearly 3,600 food process-

ing units are there in the organised sector in the State, which contribute value addition to the tune of Rs 790 crores out of the total value addition of Rs 4,800 crores in food processing industries.

Coffee Exchange to Start Functioning by Mid-April

India's first domestic futures coffee exchange, which received the Forward Markets Commission's formal approval is likely to become fully functional in Bangalore by the middle of April.

Already, the exchange has been incorporated as Coffee Futures Exchange of India (COFEI) and the authorities had been awaiting the Forward Market Commissions nod to start work on infrastructure. COFEI has already formed three committees for setting up infrastructure, recruiting personnel and enrolling members for the exchange, which is considered a step to make transparent coffee trade in the country.

The committee to enrol members for the exchange would meet in Bangalore and decide on launching membership. A capital of at least Rs. 2 crores is expected to be raised through the membership drive.

The exchange was to have begun operations in the middle of January, but could not go ahead due to delay in the formulation of by-laws. A coffee futures panel was formed to put the by-laws in shape and the rules and regulations were submitted to the Forward Markets Commission in January. There was further delay, when the commission suggested a few changes in the by-laws, which

were resubmitted after incorporating the suggestions.

Bright Prospects for Tea and Coffee; Bleak for Spices - An UPASI Survey

The any United Planters' Association of Southern India (UPASI) made an attempt to capture the views of leading industry representatives through an opinion poll on the four commodities - tea, coffee, rubber and spices.

While the opinion poll hinted rosy picture for tea and coffee, rubber and spices are expected to struggle for most part of 98.

Tea : Indian tea production during 1998 is expected to touch 820 million kgs as against 807 million kgs during 1997 and the southern production is expected to be maintained at 205 million kgs in 98.

Exports are expected to increase marginally to 195 million kgs during 1998, from 190 million kgs during 1997. The sales realisation is expected to be Rs 90 per kg in 1998, an increase of Rs 5 per kg over 1997.

The opinion poll did not visualise any shortage of tea in India during 1998. Further, most of them opined that there was no need to import tea either for the home market or for re-export in value-added form.

Though the industry's profitability is expected to remain at 1997 level, there is a general feeling that tea scrips could be bullish during 1998.

Further, there was consensus on the issue of stepped up development activities on estates.

Even as there was a feeling that global tea supplies could be less during 1998, the industry leaders thought there would not be co-operation among tea producers globally.

Coffee : The 1997-98 crop is pegged around 2.10 lakh tonnes similar to that of 1996-97. Exports during 1997-98 could drop to 1.40 lakh tonnes as against 1.81 lakh tonnes in 1996-97. However, the sales realisation is expected to be around Rs 100 per kg as against Rs 81 per kg in 1996-97.

Domestic consumption is slated to increase to 60,000 tonnes during 1998 as against 55,000 tonnes in 1997.

Further, there is a general feeling that there should be thrust in promoting consumption in non-traditional areas.

Industry is of the view that chichory- mixed instant coffee segment would lead the domestic consumption increase.

Even while admitting that strong domestic market is the mainstay for the industry, there is a feeling that producers involvement in marketing would help domestic promotion.

On the future role of Coffee Board, the industry thinks that the board should involve in promotional measures both in the global and domestic markets.

In addition, there is consensus among the industry that board should increasingly take to R & D and extension work, collection and dissemination of market intelligence and work towards quality improvement.

Spices : Cardamom and pepper prices during 1998 are expected to be lower as compared to 1997, while their production is set to improve marginally.

The industry opines that India cannot regain the lost ground in cardamom exports, while in the case of pepper, current shipments could be maintained.

High price and lack of export promotion seem to be the major factors that have kept Indian cardamom exports at lower levels.

Rothfos Sees Lower Global Coffee Output for 1997-98

In comparison to UPASI survey, forecast for global coffee output for 1997-98 is put at 97 million bags, compared with a revised estimate of 100.8 million bags for 1996-97, figures from German trader Bernhard Rothfos GmbH showed.

The forecast in the Rothfos quarterly digest was down from 98.5 million envisaged for 1997-98 in the previous estimate last November.

It was one million above a Rothfos estimate made in a company circular last month, which Rothfos said reflected continuous input to its database.

The company cited reductions in Colombian and Mexican/Central American milds as well as minor losses in the African and Asian milds segment (combined figure 39 million bags) for the lower world number.

Estimates for the crop size of unwashed Arabica were unchanged from November (24.1 million), while robusta production was now estimated to be higher (33.9 million), led by Vietnam.

The figures were based on private and public sector sources estimates and applied to 60-kilo bags on an Oct/Sept crop year basis.

Rothfos said while its estimate was similar to the latest one from statistician FO Licht, the USDA figure was much higher because of differing opinions over

Colombia, Brazil, Indonesia and Mexico/Central America.

Low Priced Tea from Tata Tea

Tata Tea will market 50,000 kg of low priced tea through government and cooperative outlets of Kerala and Karnataka. This is being done after the Consultative Committee of Plantations (CCPA) and the United Planters Association of South India (UPASI) have decided to voluntarily protect the common man from any adverse impact due to the hike in tea prices.

Under the scheme, Tata Tea would sell 100 gm tea packs and would be priced lower than the loose tea price.

The company's 10,000 kg of tea will be distributed through Neethi Stores and another 20,000 kg through State civil supplies corporation in Kerala, while in Karnataka, 20,000 kg will be marketed through government and quasi government channels.

The tea companies, which do not have packaging facilities, will be helped by firms, which have these facilities. The cost of marketing, including brand promotion, will be borne by individual companies in their respective selling areas.

In addition to Tata Tea, Harrisons Malayalam, Parry Agro, Periakarumalai, AVT, Tea Estates (Hindustan Lever) and Kotharis are some of the tea producers, who will be marketing economy pack in South India.

The major factor behind the present price rise is the substantial crop shortfall in Indonesia, Kenya and other African countries, which has led to a shift in tea purchases by importing countries to India.

The industry believes that the growth in tea exports and rise in prices may be a short term phenomenon, especially as the producing countries are expected to bounce back during 1998.

MPs' Panel Suggests Market Intervention to Check Tea Prices

The Parliamentary Committee on food and civil supplies has recommended increased market intervention to check rising tea prices.

The committee has suggested that tea producers should allocate supplies at reduced prices through central and State level co-operative outlets and fair price shops.

The suggestion from the Parliamentary Committee comes at a time when the tea industry is somewhat wary about downward pressure in prices with the prospects of improved Kenyan crop in 1998 and domestic prices levelling off to a level of Rs 80 to Rs 85 per kilogram during the first few months in 1998 compared to Rs 110 to Rs 120 per kg during the last few months of 1997.

Already the tea industry is supplying low priced and subsidised tea at an annual rate of 5 million kgs by marketing 'Nivedan' packet tea.

The Parliamentary Committee is now of the view that the producers should increase such supplies both in terms of quantum and through more marketing outlets.

The 'Nivedan' packet tea, where tea was sold at reduced prices- was recently introduced in

select government outlet supplies after the Union commerce ministry directed the tea producers to maintain supplies at least till March '98 in order to bring about some degree of market intervention. At the end of 1997, the average price per kg of tea was around Rs 72 to Rs 74 per kg on a total production of 810 millions, compared to Rs 65 per kg in 1996 on a production of 780 million kg.

The other factor, which is going to hold domestic tea prices firm, even with higher quantum of cheaper variety from Kenya and Sri Lanka coming in for exports, is the stiff export targets set by Indian tea producers.

Processing Industry's Plea for Duty-free Import of Soybean

The Soybean processing industry, threatened by an impending soybean crop shortage, has reiterated its demand of duty-free import of soybean. The industry pleaded for import as an interim measure to free it from the burden of a huge idle capacity.

The biggest bane of the soybean industry is the mushrooming growth of soybean processing units, which has resulted in a huge capacity of 15.82 million tonnes per annum created by some 168 units. Due to this, the industry's average capacity utilisation rate had never been above 25 per cent.

Due to unseasonal rains during November and December 1997, soybean, crop estimate has been revised downward to 48 lakh

tonnes from the previous projection of 55 lakh tonnes.

Poor arrivals in the markets contributed to pushing up the prices.

To get out of the supply crunch and to reverse the trend in the domestic prices of soybean the industry, through the Soybean Processors Association of India (SOPA) has urged the Commerce ministry to consider duty-free import of soybean.

SOPA to Probe into Poor Quality Soymeal Exports

The Soybean Processors Association of India (SOPA) is checking the quality of soymeal exports after complaints about poor quality meal from Philippine importers.

SOPA would launch an investigation into the complaints after obtaining details from exporters. The Philippine government has been investigating the quality of Indian soybean meal after complainants from feed-millers, who have asked for its imports to be banned.

Soymeal exports from India have dwindled in recent months as traditional buyers such as South Korea, Indonesia, the Philippines, Malaysia and Thailand are all reeling under the region's financial crisis.

South-east Asian countries import about 80 per cent of Indian soybean meal, according to SOPA estimates.

SOPA is based in Indore, the hub of India's soybean processing industry. Exporters said that there

was a problem of colour with Indian soybean meal, but it was only temporary.

Analytical Facility for Food Industry at Pantnagar

Increased consumer consciousness and globalization of trade have made excellence in quality a demand of the day. Therefore, to assist the food industry in pursuit of these endeavours, G.B. Pant University of Agriculture and Technology, Pantnagar has established an Analytical and Quality Control Laboratory (AQCL) in collaboration with the Ministry of Food Processing, Government of India and Centre for Technology Development, Bangalore. It is located in the Department of Food Science and Technology of the University. The facilities of the laboratory can be availed by food industry or any other institution or an individual to obtain an independent report of the quality of raw and processed food products as well as their ingredients and to get their personnel trained in quality control. The AQCL can also assist them in improving quality of their products and this will enable the Indian food industry to compete in national and international markets. The laboratory is well equipped to undertake physico-chemical and microbiological analyses of all types of food products and their ingredients, specially raw and processed fruits and vegetables, alcoholic and non-alcoholic beverages, spices and condiments, antioxidants, colouring matter, and thickeners, emulsifiers and stabilizers.

FEATURE ARTICLES



Natural flavours

Emulsion Stability in Food Products

Fat Replacers

Prospects for Bioproduction of Food Flavours

Nutritive Sweeteners from Starch

Emulsion Stability in Food Products

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Introduction

Emulsions in general, food emulsions in particular, have long been known to man. Fat and water are two basic ingredients of food, along with proteins, carbohydrates, vitamins and minerals. Fat and water are mutually insoluble because of their physical incompatibility. However, fat and water can be dispersed as emulsions. Food emulsions comprise a wide variety of products where either fat or water or both are dispersed in a state of macroscopic homogeneity. Emulsions occur in nature, for e.g., milk, egg yolk etc. The common food emulsions are found in many food products such as cream, butter, margarine, ice-cream, cake, chocolates etc. There are various other products that are not food emulsions in the form in which they are used, but their preparation involves emulsification, for example cake, cookie mixes, encapsulated oils and flavours. Because the contact between the fat and water is energetically unfavourable, emulsions are thermodynamically unstable and stabilizing agents are necessary to improve shelf-life of these products. However, the role of emulsifiers in stabilizing the food emulsions was well understood from the advances made in the last ten years.

Definition

An emulsion can be viewed most simply as small droplets of one immiscible liquid dispersed in

**Food emulsions
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another liquid. Many definitions are in use to define an emulsion; most appropriate ones are :

**Milk and cream are
natural emulsions
consisting of a
dispersed fat phase
in a liquid
continuous phase.**

* An emulsion is a very fine dispersion of one liquid in another

with which it is immiscible (Alexander, 1924).

* An emulsion is a two phase liquid system, consisting of fairly coarse dispersions of one liquid in another with which it is not miscible (Hatschich, 1926).

Food Emulsions

Milk and cream are natural emulsions consisting of a dispersed fat phase in a liquid continuous phase. The fat globules in milk and cream are stabilized to a considerable extent by phospholipids and to some extent by casein, albumin and globulin. Evaporated milk is more concentrated emulsion. Water is removed by evaporation and the emulsion is homogenized to promote stability. In ice cream, the milk proteins are involved in the development of a rigid layer at the oil - water interface, probably through the lipoprotein complex formation. Butter and oleomargarine are emulsions of water- in- oil with a plastic continuous phase. They contain about 80% fat and the remainder consists of salt, proteins and water. The fat phase in butter is milk fat, in margarine it may be a variety of fats or oils of animal or vegetable origin, inoculated with selected microorganisms that promote by fermentation. Stability of butter and margarine is maintained by semi-solid consistency of the continuous phase rather than

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by perfect emulsification. Egg yolk is a natural emulsion with a dispersed phase of fat. Egg yolk proteins such as lecithoproteins, lipoproteins consisting of the phospholipid lecithin are responsible for the emulsifying ability of the yolk. Egg yolk consists of about 49% of water, 16% proteins and 32% fat. Egg lipids comprise about 70% of the yolk solids and are composed of triglyceride fat (65%), phospholipids (30%), cholesterol (4%) and carotenoids, vitamins, lecithin and lysolecithin comprise about 79% of phospholipid fraction. Hollandaise sauce is an emulsion containing 40 to 50% oil, emulsified and thickened by egg yolk. The liquid in the emulsion is water and lemon juice or vinegar. The emulsion thickens during cooking to a temperature of 66 to 74°C. Gravies, sauces and cream soups are emulsions stabilized by cereal flour. Since flour does not have the emulsifying ability of egg yolk, these products must have a higher percentage of water and a lower percentage of oil for stability. Cream puff pastry is emulsion composed of water, shortening, salt, flour and eggs. Heat is applied to boil the water and melt the shortening before flour is added.

After slight cooling of the thick paste thus formed, eggs are added gradually with stirring to complete emulsification of the fat. If an insufficient quantity of egg is used, the emulsion will not form properly and the baked puffs will have low volume. Mayonnaise is a

Oil-in-water emulsions are generally white and creamy, while water-in-oil emulsions are darker and exhibit greasy, oily texture.

semi-solid emulsified food prepared from edible vegetable oil, acidifying ingredients and yolk containing ingredients. It contains not less than 65% by weight of oil. It may contain salt, sweetening ingredients and suitable harmless food seasonings or flavourings that do not impart colour simulating the colour of the egg yolk. The acidifying ingredients may include vinegar and lemon juice.

Classification

The emulsions can be broadly classified according to the composition of phases and size of the dispersed phase globules.

According to the composition of phases, the emulsions are classified into oil-in-water type and water-in-oil type based on composition of phases.

* *Oil-in-water emulsion* : This refers to a type of emulsion, wherein water is the external phase and oil is the internal phase. e.g., milk, mayonnaise.

* *Water-in-oil emulsion* : This refers to a type of emulsion, wherein oil is the external phase and the water is the internal phase. e.g., butter, margarine.

The type of emulsion can be determined in several ways, all based on the fact that the emulsion will exhibit the properties more of the external phase than of the internal phase. A visual observation may provide some initial clues. Oil-in-water emulsions are generally white and creamy, while water-in-oil emulsions are darker and exhibit greasy, oily texture. In the oil in- water type, addition of a drop of oil in to water will result in dispersion, with complete

Table 1. Classification of Emulsions based on Dispersed Phase Globules

Classification	Principal constituents	Droplet size	Type	Stability
Macro-emulsion	Oil+water+emulsifier	0.2-50 µm	Oil-in water or Water-in-oil	Thermodynamically unstable
Mini-emulsion	Oil+water+emulsifier	0.1-0.4 µm	Oil-in-water or Water-in-oil	Thermodynamically unstable
Micro-emulsion	Oil+Water emulsifier +coemulsifier	10-100 nm	Droplet bicontinuous	Thermodynamically unstable

(Becher 1965, Sherman 1968, Prince 1977)

mixing in the water, whereas in water-in-oil type, the drop will remain unchanged, usually floating on the surface, similar to an oil droplet (Petrowski, 1976).

Classification Based on the Size of the Dispersed Phase Globules

According to the size of dispersed phase globules, emulsions are classified as macro, mini and micro-emulsions. Majority of the food emulsions fall into the category of **macro-emulsions** and since these systems always have energies higher than sum of energies of the constituents, they always have a tendency to separate into two phases and are thermodynamically unstable.

Mini-emulsions are not common in food articles. However, dispersed casein micelles, which fall in the range of 0.1-1.4 μm are classified in this category, because of the small particle size they are more stable, though thermodynamic instability prevails in this system (Lack *et al.*, 1985).

Micro-emulsions are also not common as food emulsions. These are optically transparent because of the droplets of oil-in-water are too small to scatter visible light. Some micro-emulsions may not have any droplets at all. They may be bicontinuous, that is both oil and water phases may remain in continuous phase (Lindman and Danielsson, 1981).

Emulsion Stability (ES)

Emulsifying properties of proteins are important in terms of functionality of proteins in any food system. Emulsifying capacity (EC) and Emulsion stability (ES) have been used widely to determine the emulsifying properties. EC was introduced by Swift *et al* (1961), and is defined as the amount of oil emulsified by a certain unit of sample at the point of

emulsion collapse. ES is the ability of the emulsifier to stabilize an emulsion, following its formation and sometimes following certain stress conditions such as incubation, blending, centrifugation or high temperature. The amphipathic nature of proteins, because of the mixture of polar and non-polar amino acid residues, induces their adsorption at the surface of fat globules to reduce the interfacial tension. As a result, the mechanical energy required to form the emulsion can be significantly reduced. Consequently, the stability of emulsions against coalescence is improved (Haque and Kito, 1984; Kinsella, 1984, Parker, 1987).

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Sabharwal and Vakaleris (1975) studied the factors, affecting the stability of emulsions prepared by adding the appropriate amount of molten fat at 65°C to a protein dispersion in a Waring blender, stirring for 5 min at a medium speed. The dispersed system was then homogenized at 140 kg cm⁻² at 63°C. The stability was tested on standing for 24 h after centrifugation at 300g for 15 min. Stability was indicated by the fat content of the separated aqueous phase. Sodium caseinate gave maximum stability and at levels above this stability decreased significantly. The addition of calcium above 20 mM progressively enhanced emulsion stability, even though there was a considerable decrease in the solubility of casein.

Tornberg and Hermansson

(1977) compared the characteristics and stability of emulsions made with sodium caseinate and whey protein concentrate using instruments such as Ultraturax, the Sorvall omni-mixer, a valve homogenizer and an ultrasonic apparatus. Protein dispersions containing 2.5% proteins were prepared in the mixer and the pH was adjusted. Soybean oil was added directly to the protein dispersion to obtain 40% oil by weight of proteins. The samples were emulsified in an Sorvall omni-mixer consisting of a rotating, six bladed knife, which could be adjusted to 14,000 rpm. The emulsions made with the different equipments were characterized according to their stabilities. Emulsions were stored at 20°C for 24 h and then centrifuged at 180 g for 15 min at 24°C. After centrifugation, 5 ml of the lower phase of the emulsion was removed and fat is quantified. The stability rating was obtained by dividing percent fat in bottom 5 ml by percent fat in initial sample and multiplying by 100.

Graham and Phillips (1980) showed that the pH affects the stability of food emulsions in many ways. Besides protein solubility, pH affects the net charge of the adsorbed layer and hence the conformation of protein molecules affects protein load and electrostatic interaction at the oil water interface and determines the film cohesiveness and interfacial rheology.

Wedlock *et al.*, (1984) reported that if xanthan gum is used in conjunction with pregelatinized galactomannans, a synergistic interaction between them causes a large increase in viscosity that could be useful in improving the shelf-life of prepared food emulsions such as salad dressing.

De and Prasad (1987) compared the rate of creaming of homogenized milk with that of recombined milk produced by homogenizing spray-dried skim milk powder with butter oil.

Under identical homogenization conditions, they found that recombined milk had lower creaming stability than natural homogenized milk. This was attributed to the absence of phospholipids, the major component of the fat globule membrane, in recombined milk.

Factors Affecting Emulsion Stability

The apparent stability of dispersions, such as emulsions, results from the existence of interparticle forces between dispersed droplets. These forces include electrical double layer interactions, Van der Waals forces and various other interactions reflecting the presence of adsorbed layer of dissolved species or oriented molecule. The stability of food emulsions greatly depends upon the emulsifying agent, droplet size, net charge, ionic strength, viscosity of the continuous phase, density of the droplets, gravitational field, temperature, structure of the emulsifying agent and mechanical and physical properties of the adsorbed film (Kinsella, 1984).

Droplet Size

The emulsion stability depends on a balance between the attractive and repulsive forces existing between the droplets. This can be written as,

$$V = V_R + V_A$$

where V is the total potential energy of interaction and V_R and V_A are the respective potential energies of repulsion (+) and attraction (-). It follows that for maximum emulsion stability V_R should be maximized and V_A should be minimized, resulting in a maximum value of V . Another interesting fact to be noticed here is addition of inorganic electrolytes decreases the size and intensity of the droplets double layer. This would result in a decrease in V_R and a net decrease in emulsion stability. The main source of attraction between droplets V_A arises as a consequence of Van der

Waals forces or London dispersion forces. Although the short range with respect to individual atoms, when summed up over all the atoms in the droplet, the forces are long range, in its simplest form.

$$V_A = A a / 6 H_o$$

where, A is the Hamaker constant,

a is the droplet size

H_o is the distance between the particle surfaces.

The emulsion stability depends on a balance between the attractive and repulsive forces existing between the droplets.

Thus, the larger the droplet size, the greater the attractive force will be and the less stable the emulsion. The size of droplets formed depends on the type of equipment used and on the energy intensity applied during emulsion formation. High pressure homogenizers make oil-in-water emulsions with smaller droplets (Leman and Kinsella, 1989).

Temperature

The temperature associated with emulsion formation and subsequent storage are important considerations. Food emulsions are usually formed at temperatures around 60°C. The interaction of the hydrophobic groups are optimal at this temperature and interactions between emulsifiers and lipids will be optimal. Emulsion formation at this temperature will favour the interactions necessary for stable emulsions. The ability of a protein or small emulsifier to diffuse to the interface increases, as the viscosity of the

solution decreases. Thus, emulsion formation at elevated temperatures will increase the opportunities for emulsifier molecules to interact with lipids before significant coalescence can occur. In principle, the beneficial effects of decreased solution viscosity should continue as the temperature is raised beyond 60°C. In practice, the weakening of the hydrophobic association between emulsifier molecules and the lipid phase that result from the increased temperature negate any gains from increase in temperature beyond 60°C. The temperature of storage also has a significant effect on emulsion stability. As the temperature is lowered, water attains more and more structure. As the water becomes more ordered, there is less of energy difference between hydrophobic groups exposed to the aqueous phase and those buried in the oil phase. Low temperature alone does not usually cause an emulsion to break, but it can be a deciding factor in the stability of an otherwise poorly emulsified system. The largest temperature induced changes to emulsions occur upon freezing and subsequent thawing. The energy difference between the associated and free state is minimized by the low temperature, but the formation of the ice crystals causes physical damage to the emulsion. When the system is thawed, coalescence occurs and the physical damage has been extensive (Leman and Kinsella, 1989).

Viscosity

The mobility of emulsified droplets by influencing the rate and extent of collisions, affects the emulsion stability. This is determined by the viscosity of the continuous phase.

In packed food emulsions, the protein-covered oil droplets are separated by an aqueous lamellar layer. The viscosity of this layer determines the fate at which adjacent globules approach. Generally, an increase in stability is observed with increasing viscosity

of the continuous fluid (Leman and Kinsella, 1989).

pH

The effect of pH on the coalescence of droplets is one of the most important factors governing the emulsion stability. Near the isoelectric point, the emulsion droplets tend to flocculate extensively with time. Flocculation decreases as the pH is shifted away from the isoelectric point, that is droplets acquire a significant net charge. The pH exerts its effect primarily by altering the charge on the protein film. In general, the emulsion stability is maximal near the pH, suggesting that surface rigidity is important in resisting coalescence. Since the mechanism of the pH effects reflect electrostatic interactions, these become less pronounced with increased ionic strength. Thus, increasing the concentration of salt (NaCl), reduced the rate of coalescence of BSA-stabilized emulsions at pH 4.9, which is close to the pH of BSA (Leman and Kinsella, 1989).

The Nature of the Interfacial Film

The stability of an emulsion depends on the nature and properties of the interfacial membrane film. A surfactant consisting of biological macromolecules, especially proteins usually adsorb irreversibly and the properties like thickness, cohesiveness and charge of the layer formed depend on the protein and the conditions of emulsification. The surface excess of protein depends on the amount and type of protein-like molecular weight, conformation and on the conditions like pH in the aqueous phase that can affect protein conformation and aggregation (Walstra, 1987).

The type of protein used affects stability, for instance proteins with bulky tertiary structures like BSA form the more stable emulsions than caseinates, generally larger protein with residual tertiary structure from more stable

emulsions than smaller molecules with limited ordered structure.

The effect of pH on the coalescence of droplets is one of the most important factors governing the emulsion stability.

This is because they form thicker, stronger and bulkier interfacial films (Graham and Phillips, 1979).

Solubility

Several authors have observed a correlation between protein solubility and emulsifying properties. Higher concentrations of soluble proteins facilitate the formation of thicker interfacial films and smaller droplets that are

Emulsions are metastable and with time undergo destabilization, separation and breakdown in a number of ways.

more conducive to emulsion stability (Franzen and Kinsella, 1976).

Methods For Determination Of Emulsion Stability

Emulsions are metastable and with time undergo destabilization, separation and breakdown in a number of ways. In food systems, creaming is a common

phenomenon.

Emulsion stability is used as a measure of the rate at which an emulsion creams, that is, separation of the dispersed phase due to the difference in density without coalescence or changes in droplet size. The rate of these changes can be measured by determining the distribution of oil droplets in an emulsion. Thus, stability can be monitored by photography, image analysis, pulsed NMR, zeta potential measurements, centrifugation, measurement of the dielectric constant or specific electrical conductivity, velocity of ultrasound by an emulsion or by turbidometric and light scattering methods. But, though there are various methods existing for measuring the emulsion stability, one will look for a standard method. Accordingly, systematic investigations on emulsion stability by Tornberg (1978) have indicated that a standardization is quite difficult and has to be performed for each step of the experiment.

Gravimetric Methods

Smith and Dairiki (1975) determined the stability of emulsion by holding them for 24 h at 23°C and observing the gravity-induced separation using a special viewer. Stability was expressed as a stability index, based on percent phase separation or percent of total fat in the bottom half of the sample after 24 relative to percent total fat in the entire sample at zero time. Gravity-enhanced separation can be employed to determine ES, using centrifugal tests at 30°C. The stabilities of emulsions were classified according to the degree of oil phase separation, that is, no separation, separation of less than 1%, separation between 1 and 10% and separation of more than 10%. The stability rating of emulsions on the basis of the percentage changed in fat concentration in the lower aqueous phase after centrifugation. The emulsion was stored for 14h at 20°C and then centrifuged at 180 g at room

temperature for 15 min. It was assumed that centrifugation did not cause any desorption of proteins from the fat globule interface. After centrifugation of the emulsion, aliquots of the lower phase were removed for fat determination by the Gerber method. Stability rating was estimated using the following equation.

$$\frac{F \text{ test}}{F \text{ original}} \times 100\%$$

F test is the fat percentage at the bottom of 5 ml sample after centrifugation and F original is the initial fat concentration in the total emulsion.

Optical Methods/Turbidometry

The capacity of proteins to aid the formation of emulsions is related to adsorb and to stabilize the oil water interface and is related to the interfacial area that can be coated by the available protein. Similarly, the stability of an emulsion should be related to the constancy of the interfacial area. The Mie theory for light scattering by dispersed spherical particles indicates that there is a simple relationship between the turbidity and the interfacial area of an emulsion, provided that certain conditions are met. Turbidity measurements are easily made using spectrophotometer and have been applied to the study of milk fat globules, coarse colloidal dispersion and experimental emulsion.

Pearce and Kinsella (1978) used this procedure to estimate ES. Emulsions were held at constant temperature approximately at 25°C, while being gently stirred. The emulsion was then diluted serially with water and sodium dodecyl sulphate solution to give final dilution between 1000 and 5000 and an SDS concentration of 0.1%. The SDS-stabilized emulsions were then heated to 98°C and the absorbency of emulsions determined at 500 nm. An emulsion stability index (ESI) is defined as :

$$ESI = T t / T.$$

where, T is the change in turbidity, T occurring during the time interval t.

Turbidity measurements are easily made using spectrophotometer and have been applied to the study of milk fat globules, coarse colloidal dispersion and experimental emulsion.

Measurement of the Dielectric Constant

Measurement of the dielectric constant of the upper part of emulsion has been correlated with stability and droplet size. Some workers used microwave radiations to assess ES. Microwave irradiation generates heat that is proportional to the dielectric constant of the medium.

The principle of radiation method is based on the formation of a blue violet light by high energy gamma radiation in liquid media.

The dielectric constant of water is 80, while that of oil is approximately 3. When partially destabilized emulsions are heated by microwaves, the temperature of the more stable emulsions (less oil

rich) should be uniformly higher than that of the oil phase of the more destabilized emulsions. Also, the temperature difference between the surface and bottom should be less for the more stable emulsions than for the less stable emulsions, since distribution is more homogeneous in former (Noguchi and Maeda, 1973)

Pulsed NMR Measurement

Pulsed NMR measurement can be used to measure the extent of oil solidification during the cooling of an oil-in-water emulsion. Unstable emulsions show little super-cooling, whereas those that are relatively stable to creaming and phase separation are resistant to oil solidification. The percent interaction derived from these measurements or the degree of super-cooling was found to relate directly to ES. In tests for determination of emulsions stability, emulsions were aged at room temperature in constant bore tubes, which were then lowered at a constant rate through the NMR magnet. The pulsed NMR signal response was recorded, giving a profile of oil distribution throughout the tube. Since each sample can be tested repeatedly at intervals during the aging process, this approach indicates quantitatively the rate at which the phases are separating. (Trumbestas, *et al.*, 1979).

Radiation Method

The principle of radiation method is based on the formation of a blue violet light by high energy gamma radiation in liquid media. This blue violet light is called Cerenkov radiation. For its formation in aqueous systems, gamma radiation with an energy in the range of 265 keV is necessary. Due to the wide energy distribution of electron spectra, a considerable higher energy is required to induce Cerenkov radiation in turbid aqueous media like emulsions. In these experiments, this energy was supplied by a Ra 226 source with an activity in

the range of 20 mci. During the transition of Ra 226 source via Bi 214, gamma radiation in the energy of 1 to 2.5 Mev is released. This was found to be sufficient to measure the phase separation by creaming in emulsions with help of the Cerenkov radiation. The quantitative evaluation is possible, because the resulting blue violet light is highly quenched by any kind of turbidities. With decreasing turbidity in the lower part of the emulsion, the amount of Cerenkov radiation increases due to creaming. Besides phase separation, the aggregation of the fat globules leads to turbidity changes and can be followed up during the interval before creaming. The experiments were performed in a typical scintillation spectrometer with Ra 226 as the external standard radiation source (Reimerdes and Lorengen, 1983).

Emulsion Instability

Emulsions break down via a number of mechanisms. These phenomena may occur singly or in combination and different emulsion, may break down by different pathways. In emulsions, the discrete droplets are stabilized by the interfacial membrane. During emulsion breakdown, droplets approach may make contact and coalesce. In a packed emulsion, the protein-covered oil droplets are separated by an aqueous layer. The viscosity of this layer determines the rate at which adjacent globules can approach. By increasing the viscosity droplet, contact can be reduced, thereby prolonging the stability of an emulsion. While considering the emulsion stability of any food system, it is also important to look on the electrostatic and stearic factors that greatly affect the approach and coalescence of droplets. A high density charge on the film forms an electrical double layer around the dispersed globules, which cause mutual repulsion and counteract attractive Van der Waals forces. A balance between these two forces is necessary to maintain

stability according to the classical Derjaguin and Landau (1941) and Verway and Overbeek (1948) theory of colloidal stability (DLVO theory). When repulsion exceeds the absolute value of the attractive forces by a value greater than a critical amount, the emulsified particles will be stable. The DLVO theory does not explain all phenomena, affecting the stability of emulsions. It applies most validly to particles carrying an appreciable net charge. The Van der Waals attraction potential shows increasingly negative values, when the distance between the spheres are reduced, while the repulsion shows increasingly positive values. The summation of the two gives the total potential, which determines the stability of an emulsion system. For shorter distances, the attractive potential is always larger and thus, attraction is experienced. For intermediate values, the repulsion may be larger and the potential maximum is obtained. If the potential maximum is much larger than the thermal energy, the suspension will be stable.

Emulsions are thermodynamically unstable systems, but for food use reasonable stability (from few weeks to few months) is required. The stability of food emulsions declines with time. Although the causes of instability can be explained by the thermodynamics, thermodynamic arguments can be improper and misleading in explaining such kinetic events (Darling and Birket, 1987). For example, in emulsions with small droplets, which have larger surface area, the free energy of the system is greater than that of a similar emulsion with bigger droplets. However, this does not necessarily mean that an emulsion with a larger surface area is less stable than one with a smaller surface area, but in fact, the opposite is generally true (Tornberg and Ediriweera, 1988).

The classical theory of emulsion stability in terms of various interaction forces, although important in understanding the in-

stability of the system, it can not be predicted how long an emulsion will remain stable. Since predictability of stability is essential in the development of food products, practical assessment of emulsion stability through the experimentation is the usual approach.

In addition, stearic factors that are bulky side chains or substituent groups and hydrated groups projecting into the continuous aqueous phase, tend to impede close approach of the film around neighbouring globules and prevent Van der Waals and perhaps, hydrophobic forces from becoming effective. Hydration of the adsorbed protein film may contribute to the stabilization of emulsion droplets.

The mechanical and rheological properties of the adsorbed film also contribute to the emulsion stability. The thickness of the film, its restorative properties, its elastic, dilatation and viscosity attributes govern its resistance to desorption, when two droplets make contact, thereby enabling it to withstand physical and thermal shocks and maintain stability.

The stability requirements of different food emulsions vary, for example, food emulsions like cake batters need to be stable for only hours, whereas other food emulsions like mayonnaise need to remain stable for years. Thus, food emulsions with both short term and long term stability are needed. Short term stability can be provided by using small surface active compounds that reduce the surface energy and facilitate emulsion formation (Charalambous and Doxastakis, 1989). These small surface active agents form an interfacial film that prevents immediate coalescence. Long term stability is usually provided by employing macromolecules, such as proteins and polysaccharides (Dickinson and Stainsby, 1988; Charalambous and Doxastakis, 1989).

There are several processes in an emulsion that cause instabili-

ty. These include creaming, flocculation, coagulation, coalescence, oiling off (Halling, 1981; Darling and Birkett, 1987) and Ostwald ripening. These are not much different from each other. For example, flocculation and coagulation essentially refer to the same phenomenon of droplets touching each other without losing individual identity. It is referred to as flocculation, when a cluster comprises only a few droplets. However, when a large number of droplets are involved, it is often regarded as coagulation. An important difference between flocculation and coagulation is that the former is usually reversible while the latter is not. Similarly, oiling off is the result of extensive coalescence, but coalescence may not necessarily involve oiling off. Many of the processes mentioned above do not occur independently, for example, flocculation enhances creaming and if it leads to coalescence, further enhancement of creaming occurs.

Creaming

Since the densities of most edible oils and melted fats are lower than water, there is always a tendency of the phase to concentrate at the top of the food emulsions. The rate of creaming (V) depends on the droplet size (d), density difference (e) between oil and the aqueous phase, and the viscosity (n) of the medium as expressed by Stokes equation :

$$V = \frac{egd^2}{18n}$$

where d is the diameter of the droplet and g the acceleration due to gravity. A 1 μm diameter droplet of oil ($e = 0.9$) will rise about 5mm in 24 h through a continuous phase of viscosity of 1 cP at 25°C, Stokes equation is strictly applicable only at infinite dilution of spheres, where there is no inter droplet interaction. Under ordinary conditions, there is considerable inter droplet interaction

even in dilute emulsions. Also the, density of oil might be considerably altered because of the influence of the adsorbed emulsifier layer around the droplet, particularly if the droplet size is small.

Flocculation is defined as the process by which two or more droplets aggregate without losing their identity.

Various factors such as particle interaction in foods, droplet aggregation, emulsion polydispersity, non-Newtonian nature of the continuous phase, thickness of the adsorbed layer and the centrifugal force affect the creaming rate (Darling and Birkett, 1987).

Creaming is usually reversible because gentle shaking can re-disperse the creamed layer in most cases. However, if an emulsion is allowed to cream for a long time

Coalescence is the process by which the collision of two or more droplets results in the formation of one bigger drop.

or if the creaming is done in a centrifuge, extensive droplet aggregation and inter droplet bridging may occur and eventually result in separation or oiling off. Thus, extensive creaming may not be reversible.

The phenomenon of cream-

ing can be extensively reduced in food emulsions, by increasing the viscosity of the continuous phase. This is accomplished by addition of hydrocolloids such as polysaccharides, various gums such as guar gum, gum arabic and xanthan gum and other polysaccharides such as carboxy methyl cellulose (CMC), starch, pectins and alginates (Morely, 1984; Philips *et al*, 1984).

Flocculation

Flocculation is defined as the process by which two or more droplets aggregate without losing their identity. Flocculation occurs because of net attractive interaction between different droplets. Food emulsions containing $>2\mu\text{m}$ flocculate quickly under shear flow. The presence of macromolecular emulsifying agents in an emulsion can induce flocculation by polymer bridging between droplets. This may occur, when the macromolecule concentration is insufficient to cover the interface created during homogenization (Darling and Birkett, 1987). This also happens in systems containing concentrated droplets, for example in homogenized cream or in the creamed layer of an emulsion. Flocculation can result in the formation of an extensive network of interconnected droplets and increase emulsion viscosity. The flow properties of emulsions become non-Newtonian thixotropic, i.e., emulsion viscosity decreases with increasing rate of shear as the network is disrupted (Das and Chatteraj, 1980; Darling, 1982). Bridging flocculation depends on the size, conformation and type of emulsifier (Vincent, 1974). Since small molecule surfactants can displace proteins from the interface, they reduce the flocculation of the protein-stabilized emulsions. The effectiveness of small molecule emulsifier in decreasing flocculation varies in the order : Lecithin $>$ Tween-80 $>$ Diglycerol monoester.

Coalescence

Coalescence is the process by which the collision of two or more droplets results in the formation of one bigger drop. This process essentially reduces the net surface area of the emulsion system and is associated with a decrease in surface energy. Coalescence is the principal cause of instability of emulsions, as it involves breaking of the interfacial film and is irreversible. Various factors, such as solubility of the emulsifier, pH, salts, emulsifier concentration, phase-volume ratio, temperature and properties of the film, affect coalescence stability of the emulsions.

Ostwald Ripening

Ostwald ripening refers to the diffusional transport of the material from smaller droplets into larger ones. The chemical potential is higher in droplets with a large radius of curvature. This difference in chemical potential can serve as the driving force for the transport of the material. Recent work by Dungan and McClements (1993), has demonstrated that such transport can occur in emulsions formed from lipids having different melting points. When mixtures of two emulsions were made and aged in the presence of excess emulsifier, it was possible to demonstrate the existence of lipid droplets having melting points intermediate between those of the original lipids. The rate of transport was directly related to the concentration of free emulsifier molecules, which presumably served as carriers for the transported lipids. Interestingly, during the time of the experiments, the size distribution of the emulsions did not change. If significant Ostwald ripening were to occur, the average droplet diameter would be expected to increase. In emulsions stabilized by proteins, Ostwald ripening probably has little impact upon emulsion stability.

Emulsion Stability of Proteins

In one of the studies conducted by Hung and Zayas (1991) on evaluation of the emulsion stability of corn germ protein flour (CGPE), sodium caseinate (SC) non-fat dry milk (NFDM) and whey protein concentrate (WPC), these workers showed that the emulsion stability of milk proteins is far superior than that of other proteins. That was in the order of SC → WPC = NFDM → CGPE.

The emulsion stability of milk proteins that is sodium caseinate followed by whey

For emulsifiers to concentrate at the interface, they should be neither extremely water soluble nor extremely oil soluble.

protein concentrate can be attributed to the high surface activity of α -S₁ and β -casein, the major components of sodium caseinate (Dickinson and Stainsty 1988). and also the above statement can be supported by the fact that each protein system exerts its own unique influence on the emulsion stability, since each possesses a characteristic complement of amino acids that controls its ability to adsorb at the interface and to produce a stabilizing film surrounding the oil droplets, protecting them against flocculation, coalescence and oiling off.

Emulsifiers

In the search of improving the emulsion stability, certain compounds were found to impart a very essential attribute, i.e., stability in some of the food systems. These substances are called

emulsifiers and further investigation has revealed that these compounds have a remarkable property of lowering the interfacial tension between the two phase systems like emulsions, by way of concentrating at the interface or at the surface. Hence, they are also named as surfactants or surface active agents.

For emulsifiers to concentrate at the interface, they should be neither extremely water soluble nor extremely oil soluble. Such solubility requirements are possible, if the molecule contains both a polar and a non-polar portion. Emulsifiers, which have been classified by Schwartz and Perry (1949), are applicable till today. The classifications are given below:-

- * Anionic : e.g., Salts of long chain fatty acids.

- * Cationic : e.g., Amine salts such as acetyl trimethyl ammonium bromide.

- * Non-ionic : e.g., Mono-glycerides.

The hydroxyl groups and polyoxyethylene chain are the polar of hydrophilic portions and the fatty acid chain and carbon skeleton are the non-polar lipophilic portion of the non-ionic emulsifiers. From the time of the discovery of the emulsifiers to the present, the number of these surface active agents has increased logarithmically.

Desirable Characteristics of Emulsifiers

The ideal emulsifier should

- * Have sufficient hydrophobicity to ensure solubility over a wide range of pH

- * Have sufficient hydrophobicity to ensure solubility over a wide range of pH

- * Have high adsorption capability and low surface or interfacial tension

- * Have well balanced dis-

tribution of hydrophilic and hydrophobic domains throughout the molecule.

- * Be able to form a cohesive film at the oil water interface.

- * Have high degree of conformational flexibility and strong interaction at the interface.

- * Have high charge density, preferentially exposed to the aqueous phase to create electrical repulsion barrier and reduce droplet approach and coalescence. (Halling, 1981 ; Kinsella 1984 ; Walstra 1987)

The choice of emulsifier should be based on the evaluation of some characteristics of the emulsifier and on this basis may exist. The idea that an emulsifier molecule should contain a balance between polar and non-polar moieties was pointed out by Clayton (1943).

Differences in solubility provided an initial differentiation among the relative polarities of emulsifiers. The more polar emulsifiers tended to be more soluble in water and promoted the formation of oil-in-water emulsions. Less polar emulsifiers tended to be oil soluble and promoted the formation of water - in - oil emulsions. This approach was further delineated in quantitative terms by Griffin (1949, 1954) with the introduction of the experimental procedure and he was able to assign values to emulsifiers ranging from lipophilic to hydrophilic using a scale of 1 to 20, arbitrarily assigned to oleic acid and potassium oleate, respectively.

Emulsifier HLB range and applications are given in Table 2.

The concept of HLB system simply says that a specific emulsifier HLB is required to produce a particular type of emulsion. The number indicates essentially, the ratio of the percentage weight of the hydrophilic portion of the emulsifier molecule to that of the lipophilic portion of the emulsifier. In another way, it represents one fifth of the percentage of

hydrophilic portion of the emulsifier. Therefore the whole HLB scale ranges from 0-20. In a simple oil-in-water emulsion, the fact that the emulsifier molecule is oriented at the oil-water interface is not sufficient to stabilize the emulsion particle. Instead, the stability of the emulsion is dependent on the relative strength of the hydrophilic

The emulsifiers have wide industrial applications and the choice of an emulsifier depends on the length of the stability required.

and lipophilic groupings of the emulsifier used, that is the HLB of the emulsifier. Thus, at a lower HLB, since the hydrophilic groupings are weaker, the bare fat globule is weakly associated with the aqueous phase and hence the emulsion is unstable. At a higher emulsifier HLB, since the hydrophilic groupings are stronger, the bare fat globule is strongly associated with the aqueous phase and hence the emulsion is stable. However, if the HLB of the emulsifier used is ex-

tremely high, the hydrophilic ends would be so strong as to make a weak orientation of the lipophilic ends into the lipid phase. In such circumstances, there would be instability (usually when the HLB is 16).

Calculation of HLB Value of An Emulsifier

When the structure of a polysorbate type of emulsifier molecule is known, the HLB value can be calculated from the relation,

$$HLB = (E+P)/5$$

where E is the weight percentage of oxyethylene content and P is the weight percentage of polyhydric alcohol content. This method works well for the series of sorbitan and polyoxyethylene sorbitan esters, but suffers from its limitations not applicable to non-ionic surfactants containing other hydrophilic oxide units, sulfur or nitrogen containing surfactants or ionic surfactants (Griffin, 1954). By examining the HLB values for a large number of emulsifiers, Davies (1957) was able to derive group values for the structural moieties of the molecules in the following equation.

$$HLB = 7 + (\text{hydrophilic group numbers}) - (\text{lipophilic group numbers})$$

Table 2. Emulsifier HLB Range and Applications

HLB range	Applications
04-06	Water-in-oil emulsifier
07-09	Wetting agent
08-18	Oil-in-water emulsifier
13-15	Detergent
15-18	Solubilizer

(Griffin, 1949)

Application of Emulsifiers

The emulsifiers have wide industrial applications and the choice of an emulsifier depends on the length of the stability required. Thus, many polysaccharides have limited surface active properties and consequently can stabilize emulsions. Gum arabic or gum acacia reduces the surface tension of water, very slowly over a period of 3 to 4 days and forms an interfacial film. It produces a stable emulsion with most oils. Methyl cellulose and hydroxypropyl methyl cellulose possess surface active properties (Grover 1982). They are used with sodium alginate in the stabilization of non-dairy whipped toppings for salads and desserts. Methyl cellulose ethers stabilize whipped emulsions that can be spray dried and then recombined with water, while whipping to produce emulsions suitable as toppings, fillings, custards or puddings. Tara gum in combination with xanthan gum is reported to act as an emulsifier for processed marine foods and improve emulsion stability and water retention (Glicksman, 1982). None of these polysaccharides causes much reduction in the interfacial tension and considerable energy is required to make stable emulsions.

The emulsifiers have wide applications in the soft drinks industry. They are used mainly as clouding agent, usually in the form of flavouring oil. The characteristic nature of these substances that is ideally suspended in the beverage neither sinking to the bottom to form a sediment nor rising to the surface to form a ring over an expected shelf-life of one to two years. Such stringent requirements were met, until recently by the use of Brominated Vegetable Oil (BVO). When BVO was mixed with the flavouring oils, the resultant mixture possessed a density similar to that of the aqueous medium. Thus, there was little tendency towards rising or settling. After the Food and

Drug Administration severely restricted the use of BVO, a similar increase in the specific gravity of the oil was brought about through the use of an approved additive, glycerol abietate. In the field of pharmaceuticals, maximum stability of ointments and release of active ingredients has been achieved by the use of emulsifiers.

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Fat Replacers

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Introduction

Fat plays a key role in a majority of food products. Fat provides a creamy texture and a flowing mouthful to foods. It contributes to the food, various organoleptic and rheological characteristics such as flavour, mouthfeel, body texture, etc. These attributes contribute to the richness of the food product, resulting in better market value and consumer acceptability with regard to high cholesterol content and energy levels. Fat has been implicated in various health disorders, in particular, the cardiovascular ailments and obesity (Schaefer, *et al* 1996).

Concern over the intake of dietary fat has triggered consumer demand with low or no fat foods. By the removal of fat in food, many of the physico-chemical properties get altered. In view of this, a low consumer response is observed towards these products. The demand carries formulation challenges for food technologists to compensate for the loss of body and mouthfeel, opacity, slip, mouth coating, flavour masking, fatty flavour and a variety of other functional properties. To accomplish this, there is a need for suitable ingredients, which is/are non-toxic, cost-effective and able to mimic the fat without increasing the calorie intake (Buss, 1993).

In the early eighties (Denhemies, 1992), the use of fat replacers was unthinkable. How-

ever, during the last ten years, a considerable interest has been shown towards the low fat or no

Fat has been implicated in various health disorders, in particular, the cardiovascular ailments and obesity.

fat foods. This is substantially due to the health concern. In the recent years, world market has been flooded with the food products

Fat replacers are ingredients used to replace the fat in a food system.

carrying the label "low fat" and "no fat" (Anon, 1991 b).

What Are Fat Replacers ?

Organoleptically, fatty or oily mouthfeel can be described as a combination of several basic

parameters which together form the recognizable edible sensation of fattiness or oiliness. These parameters are viscosity (thickness, body, fullness), lubricity (creaminess, smoothness), absorption/ad-sorption (physiological effect on taste buds), and few others. These are the functions of fats. It is very difficult to replace the functions of fats in foods, but that is what fat replacers are designed to do. Fat replacers are ingredients used to replace the fat in a food system.

However, the process of replacement is not an easy job. The role played by fat to contribute various characteristics like taste, texture and appearance to foods is very complex and is difficult to simulate the same by use of other substitutes (Schaefer, *et al* 1996).

Types of Fat Replacers

Basically, fat replacers have been categorized as those which include fat substitutes, fat mimetics and bulking agents (Schaefer, *et al* 1996).

Fat Substitutes

Fat substitutes are similar to fats and can be defined as compounds that replace triglycerides in foods. Examples are olestra, salatrim, caprenin and sorbestein. The most prominent examples right now are olestra and salatrim. Olestra is formed by reacting sugars with fatty acids. Because of the spatial configuration of these

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fatty acids around the inner core of the sugar molecule, it cannot be digested. It passes through the body without providing any calories. Salatrim, is a modified triglyceride. It contains long chain fatty acid and two short chains, it is partially digested and provides 5 Kcal/g.

Fat Mimetics

Fat mimetics are carbohydrates or proteins and are used to replace fat in foods because of their textural or organoleptic properties. There are many carbohydrate-based fat replacers available for use in foods. Most are modified food starches or maltodextrins. These short chain carbohydrates mimic the mouthful that fats provide in foods. They are totally digested and provide 4 Kcal/g. Protein-based fat mimetics are extremely small and have a spherical shape. This allows them to provide smooth-flowing layers in foods in which they replace the fat. One example of this is, simplesse, which is made from milk proteins and egg white.

Bulking Agents

With the use of high intensity sweeteners in foods, other is a need to provide body and texture normally contributed by sugar. The non-caloric bulking agents fulfil this role.

They can also be classified on the basis of their origin and chemical nature, as (i) Carbohydrate-based, (ii) Protein-based, (iii) Synthetic ones (Anon, 1991 c).

In some cases, a fat replacer can be only an essential ingredient to perform the desired function, while in other cases, a combination of fat substitute depends on the type of the food product, the replacement level and the initial fat content.

Carbohydrate-based Fat Replacers

For more than a decade,

some carbohydrates and carbohydrate-based materials have been used partially or totally to replace fat or oils in a wide variety of food products. They exhibit desirable properties, like water binding, which improves the rheological properties, viz., body,

Fat mimetics are carbohydrates or proteins and are used to replace fat in foods because of their textural or organoleptic properties.

texture, viscosity and consistency of the product. They are better acceptable to those foods, which contain some water and are not suitable for solid foods like biscuits or snacks (Anon, 1990). The various carbohydrate-based substitutes are as follows :

Food Gums

They are also referred to as hydrophilic colloids (β -glucan, maltodextrins, bulking agents,

Food gums are long-chain polymers, predominantly carbohydrates in structure and all are soluble or swellable in aqueous systems.

fibres etc. are included under this category). Food gums are long-chain polymers, predominantly carbohydrates in structure and all are soluble or swellable in aqueous

systems to give the slippery, creamy viscosity that makes them useful as fat-mimetic agents. They provide thickening or viscosity in all cases and also gel in many cases. In addition, they have many associated functional properties such as emulsifying, whipping, stabilizing, encapsulating, etc. Over the past 15 years, researchers have shown that hydrocolloids physiologically function as soluble fibres when ingested and as such, are very effective in reducing blood cholesterol levels and moderating glucose responses in diabetics. They have the ability to mimic and replace the fat in processed foods. They find wide applications in a variety of foods such as bakery, beverages, breakfast cereals, condiments, sauces, seasonings, confectionery products, dairy products, meat, fish poultry products, pet foods, salad dressing, snack foods, sugars and sweeteners. Used at low levels, usually in the range of 0.1-0.5 percent, gums dramatically increase viscosity, leading to emulsion stability (Glicksman, 1991).

Cellulose Gel

Cellulose is the main constituent of the plant cell wall. This is hard to digest as the human intestine lacks the cellulose digesting enzyme, cellulase. Cellulose with other inert polysaccharide constitutes the indigestible carbohydrate of the plant foods, i.e., vegetables, fruits or cereals, which are referred to as dietary fibres. Dietary fibre is mainly important in the maintenance of intestinal mobility, i.e., Peristalsis. Its microcrystalline form is used to substitute the fat. Microcrystalline form is formed by partial depolymerization of cellulose. It has a molecular weight of 30-50 Kdal (Pszczola, 1991). It is water insoluble but does not form fibrous structure. It is marketed under the trade name Avicel. It has been found a niche by providing the rheological and mouthfeel properties. There are two types of

Avicel™ RC and CL, which when dispersed, form colloidal dispersion of insoluble cellulose particles with a typical particle size of 0.2 μ m. A 1.2 percent dispersion of RC-591 will form soft creamy gel with a typical setup viscosity of 1,250 cps. These gels are rheologically similar to oil-in-water emulsions. A 1.0 percent dispersion of RC-591 cellulose gel, when added to 20 or 30 percent simple emulsion, will add back the rheological and mouthful properties of a 60 percent oil-in-water emulsion. However, in the low pH system, a protective colloid must be used to keep the microcrystals in suspension. Xanthan gum or cellulose gum is recommended for this purpose. The typical examples where the cellulose gel is being currently used are the frozen dairy desserts, salad dressings and sour cream (Penichter and McGinley 1991).

Starch Derivatives

It had been found many years ago that starch degraded to lower molecular weight compounds with low dextrose equivalent (DEs) had fat mimicking properties. DE is a measure of reducing sugar content calculated as percent dextrose on dry weight basis. The DE of the starch is zero while that of dextrose is 100 (Glicksman, 1991).

Starch derivatives can be further classified as :

Maltodextrins

Maltodextrins are obtained by partial enzyme hydrolysis of nutritional saccharides and subsequent spray drying of the native starch. During enzyme hydrolysis, amylose and amylopectin chains are cleaved. The degree of polymerization of the maltodextrin produced is significantly associated with its functionality. However, maltodextrins with low DE value are considered to be more suitable as fat substitute. In the production of maltodextrins, any α -amylase enzyme suitable for starch liquefaction can

be used (Inglett and Grisamore 1991).

Maltodextrins can be further classified depending upon their source of production.

Potato Starch Maltodextrin

It is manufactured by enzymatic hydrolysis of potato starch. Currently, it is being produced under the trade name "Paselli SA2 (Harkema, 1991) and "C' Pur 01906". These mainly differ in terms of their DE values, method of preparation and their application. The DE values of Paselli and C' Pur 01906 are 5 and 2-5, respectively. The widely acceptable fat replacement properties of Paselli SA2 are applicable to

Maltodextrins are obtained by partial enzyme hydrolysis of nutritional saccharides and subsequent spray drying of the native starch.

products such as low fat desserts.

Boiling of 15% aqueous solution of C01906 produces solid gel and a gel with 20% C01906 has a butter-like consistency, when stored at 4°C. These gels are thermoreversible and are formed at room temperature under UHT conditions. Consistency is not affected by the addition of sucrose, sugar substitutes, modified starches and other starch saccharification products. Furthermore, the pH value of the products manufactured (between pH 3-7) has a negligible influence on the strength and consistency of gels or products manufactured with C01906 and can withstand (the gels) the effects of shearing and heating and they can tolerate homogenization and UHT conditions (Dorp, 1994).

Properties of C' Pur 01906 show that it can be used in a variety of foodstuffs, not only as a fat replacer, but also as a stabilizer and as a body and viscosity enhancing agent. With ice cream, these factors may be influenced by the use of this maltodextrin, namely fat reduction, viscosity of the mix and mouthfeel. Its excellent suitability for mixing with butterfat and other vegetable oils and fats such as palm kernel fat or soy oil further expands its potential use. The caloric value of C' Pur 01906 is 16 KJ/g, a conspicuously lower value than that of oils and fats, at around 28 KJ/g. This results in a caloric reduction of about 30% in "fat free" ice cream, as compared to traditional ice cream. By incorporating this ingredient, it is even possible to achieve a fat reduction of hundred percent.

Properties of Potato Starch Maltodextrin

These are :

1. Appearance - Free flowing white powder
2. Odour and taste - Bland
3. Moisture content (%) < 5
4. pH 4.5 to 5.5
5. SO₂ (ppm)
6. DE > 3

The limit for use of C' Pur 01906 is reached at 3.5% in ice cream and in dairy sector in general. Above this limit, the taste is impaired due to characteristics of the product, which could only be compensated by an extreme amount of flavouring.

Another, modified potato starch, called Stra-Slim™ 143, may be used to partially replace fat and oils in a wide variety of food products. This ingredient provides the mouthful and texture usually furnished by fats and oils. It has a calorie content of 4 Kcal/g as against 9 Kcal/g provided by fats and oils. Products for which it is recommended include

pourable and spoonable salad dressings, cheese cakes, imitation cream cheese and soups (Dorp. 1994).

Polydextrose

A low calorie polydextrose derivative, for use as a fat replacer etc. in foods is based on at least one fatty acid and at least one polydextrose product prepared from glucose, sorbitol and polycarboxylic acid catalyst. The fatty acid may be a C₈-C₂₂ polyunsaturated fatty acid, or a blend of C₈-C₂₂ saturated and unsaturated fatty acids, especially C₁₄-C₁₈ fatty acids. The polydextrose derivative has a degree of substitution in the range of 0.1-3.5, preferably 0.8-3.5. A polymer of dextrose with small amounts of sorbitol and citric acid is produced by Pfizer chemicals. This water soluble amorphous solid has a caloric value of 1 Kcal/g. Although it is marketed primarily as a bulking agent, polydextrose may be used as a partial substitute for fat.

Food applications include use in candy, chewing gum, candy coating, frozen dairy products, dry mixes, nutritional bars, puddings, dry cake and cookie mixes, frostings and icings. It is also approved as a food additive for foods for special dietary use.

Corn Starch Maltodextrin

It is a non-sweet saccharide polymer produced by a limited hydrolysis of corn starch. This oligosaccharide consists primarily of a 1-4 linked dextrose units, which are capable of being converted into Maltose, called maltrin M040. This maltodextrin is a white spray-dried powder, having a dextrose equivalent of 5. It is completely soluble in hot water and forms thermoreversible gels, when cooled. These gels are characterized by a bland flavour, smooth mouthfeel and a texture similar to that of hydrogenated oil. Grain processing corporation has conducted a number of application tests, which show that Maltrin 040,

alone or in combination with other maltodextrin, may be used to reduce the fat levels of foods such as low-fat table spreads and margarine, imitation sour cream, salad dressing and frozen desserts. Standard margarine contains 7 Kcal/g and a typical M040 reduced calorie table spread contains about 4.5 Kcal/g. It is also reported that the M040 spread has the mouthfeel, flavour and spreading properties of margarine. A formulated imitation sour cream prepared

**Oatrim is
maltodextrin made
from oats and is a
fat substitute with
the ability to lower
blood cholesterol
level.**

with M040 was judged to have acceptable flavour, texture and mouthfeel, although the fat content was only 50% that of a standard sour cream (Anon, 1991 a).

Stellar : It is another corn-starch based fat replacer, prepared by controlled acid hydrolysis of corn starch. Fat-like properties arise from the particle gel structure developed on shearing the insoluble starch product in water produce a firm deformable cream. This cream is composed off loosely aggregated sub-micron size particles. This can reduce the fat content of such food applications as margarines, cheese spread and baked goods while maintaining texture, mouthfeel, stability and visual qualities of full-fat products. It enables the food manufacturers to replace the fats with fully digestible, complex carbohydrates (Anon, 1991a).

Tapioca Maltodextrin

It is principally obtained from tapioca starch. It is produced

under the trade name N-Oil^R, which is prepared by heating tapioca starch in the presence of hydrochloric acid. This treatment causes reduction in the viscosity of cooked starch dispersion, which gives rise to gel formation. It is thermally reversible and has fat-like properties. It can be used in products like pourable and spoonable salad dressings, puddings, margarine-type products, table spreads, imitation products such as imitation sour cream etc. Its instant form is marketed as N-Oil-II and is having usage in the production of microwave cheese sauces.

Oat Maltodextrin

Oatrim is maltodextrin made from oats and is a fat substitute with the ability to lower blood cholesterol level (Labell, 1992). This ingredient can lower cholesterol in two ways :

1) By serving as a replacement for animal fats, such as dairy creams or lard, in the diet, and 2) By the action of its component β -glucan, which lowers total blood cholesterol, with increase in the good HDL cholesterol and decrease in the bad HDL cholesterol.

Its patented process involves the conversion of oat starch in the flour or bran to maltodextrins using α -amylase for starch liquefaction. The conditions of enzyme treatment are selected to achieve conversion of the substrate so that the soluble fibre bound in the cellular matrices are liberated. There are three types of oatrim, namely oatrim-1TM (Kachner, 1991), oatrim-5TM and oatrim-10TM. These differ mainly with respect to the approximate percent of β -glucan present in the ingredient on a dry weight basis and are prepared from debranned whole oat flour, whole flour and oat-bran, respectively. It is claimed that oatrim has an excellent fat-like quality, which is better than gels of maltodextrin from other sources like potato, tapioca, corn, etc. Due

to its component β -glucan, it has a hypocholesterolemic or cholesterol lowering property. It forms gel on heating and on cooling, forms a 25 % dispersion. Its food uses are based on fat-like property, viscosity, appearance and taste of oatrim powder or its gel. The application ranges from icecream and frozen desserts, milk shakes, breakfast cereals, salad dressings, egg nogs, baked products, margarine, meat, dietetic foods and various other products, where body texture play an important role in consumer acceptance (Inglett and Grisamore 1991).

Lean MakerTM : This is another oat-bran-based fat replacer, when used with 90 percent fat-free ground beef or pork sausage, is reported to provide the texture, flavour and juiciness of full-fat meat product. This is composed of specially processed oat-bran with flavourings and seasonings (Anon, 1991e).

Modified Food Starches

Previously cited stellar is, sometimes, included in this category. Its potential (Stellar's) uses included as an antistaling agent for baked goods, as stabilizer, toughening inhibitor for microwave heated bakery products and as a fat replacer in low fat salad dressings, margarine-like table spreads and cake frostings (Harris and Day 1993).

In another patented process (Okhuma *et al* 1993), an indigestible dextrin is prepared by acid treatment of corn starch to get pyrodextrin, which is further hydrolyzed with α -amylase and gluco-amylase to yield a hydrolysate with removal of 50% glucose. This hydrolysate contains fractions other than glucose having 90% of indigestible components, 25-35 % glucose residue has 1-4 glycosidic linkage and has an average molecular weight of 900-1300. Indigestible dextrin can also be produced from potato starch by initial acid treatment, using HCl

and further heating at 120-200°C using an extruder. The product obtained contains 50% of 1-4-glycosidic linkage and about 60 % of an indigestible component (Glicksman 1991).

AmaleanTM, is a high amylase product, marketed by American Maize Products Co., USA and has been claimed to be suitable for 100% replacement of fat in baked foods, sauces, dairy products, as well as in a variety of

Inulin from chicory roots is a mixture of glucose-terminated, β - 2,1 linked fructans that can be used as bulking agent or low- calorie bifidogenic dietary fibre and is suitable for diabetics.

other food products (Glicksman, 1991).

Another rice derived product, has a combination of micro-particulated protein and a gelling carbohydrate and gels at low temperatures. This ingredient is fully metabolized in the body and energy output values for the powdered form and a 25% gel are 4 and 1 kcal/g, respectively. It has a lower viscosity at a given solid content *vis-a-vis* rice starch. So, more of it can be used in replacing fat in the food product to get a desired consistency. The product is natural, sulphite-free, hypoallergenic and bland. It may also be called rice protein or hydrolyzed rice solids. A different form of this product, Rice Complete 3, can perform multi-functions like moisture retention, increasing the volume and yield in baked foods and as a natural adhesive for rice cakes.

Other starch-based fat

replacer, Tapiocaline EX533, is used in the preparation of Beef Burgers. Tapiocaline is made by extracting cassava starch from cassava flour. It is then heated to cause partial gelatinization. Its properties are intermediate to those of native and instant starches and it has particle size intermediate to those between 80 μ m and 3.25 mm. Tapiocaline was used at hydration ratios of 1:3 and 1:4 in a beef burger recipes, containing beef forequarter and salt (Hart and Price, 1993).

Another, gel-forming starch hydrolysate (manufactured from potato starch) is neutral in flavour, and has good water solubility. At a concentration of 25-30% by weight, it forms spreadable gels of a consistency similar to edible fats. At concentration greater than 30%, it forms firm, sliceable gels. The gel melts at 50-70°C and reset on cooling. Applications include use as a fat replacer in calorie-reduced products, a thickener, a bulking agent, a stabilizer, a protecting agent in drying of heat-sensitive product (Richter *et al*, 1975).

Other Carbohydrate-based Fat Replacers

Inulin

Inulin from chicory roots is a mixture of glucose-terminated, β -2,1 linked fructans that can be used as bulking agent or low- calorie bifidogenic dietary fibre and is suitable for diabetics. It is marketed under the trade name RaftilineTM. It improves the body and texture, mouthfeel, increases gelling capacity and stabilizes emulsions. Other uses, include baked goods, beverages, desserts etc.(Franck, 1992).

Pectin

It has been described as "Nature's own Fat Replacer". Fat Replacer called SlendidTM (Dorp, 1994) is a proprietary form of pectin that has applications in frozen

desserts, dressings, soups, cakes, cookies, processed cheeses, yoghurts, and a variety of other food products. When replacing fat, it provides a creamy, fat-like texture and mouthfeel that is needed in low-fat or no-fat applications (Anon, 1991c). Pectin is a hydrocolloid, consisting mainly of the partial methyl esters of polygalacturonic acid. The acid groups are partly neutralized by ammonium, calcium, potassium and sodium ions. Pectin is obtained by aqueous extraction of appropriate plant materials such as citrus peel and apples (Christiansen and Edalsten, 1993).

Hemicellulose

Hemicelluloses are generally defined as plant polysaccharides that are extractable by aqueous alkali solutions, with the exclusion of the typical water soluble gums and starches. Chemically, they are a heterogeneous group of polysaccharides, which contain a variety of different sugars in the polymer backbone and side chains. They are generally classified by the monosaccharides in the backbone—normally, xylose, mannose, or galactose and have side chains commonly of arabinose, galactose and glucose. Typical examples are the cereal hemicelluloses referred to as Pentosans, which contain

monomers of xylose and arabinose (Anon, 1991b). These monomers may contain 2-4 of these various sugars, and the polymer chain usually contains 50-200 monomers per molecule. Useful hemicellulose components have also been identified in other available plant materials. These include Fibrex sugarbeet fibre. Fibrim soy fibre and AF fibre almond fruit fibre (Glicksman, 1991).

Protein-based Fat Substitutes

Ingredients derived from proteins found in egg, milk and other foods, have been developed for applications as fat substitutes (McCarthy and Maegli, 1994). Presently, many commercial protein-based fat substitutes are available in the market and are cited as follows :

Casein-based Fat Substitute

In a concentrated form, non-aggregated casein micelles have also found applications as a fat substitute in food products such as frozen dairy desserts, icings, dips, spreads and sauces.

Simplese, a low calorie protein-based fat substitute, was introduced in January 1988 and in 1990, FDA confirmed the GRAS (Generally regarded as safe) status

of the fat substitute in frozen desserts (Anon, 1988a).

Simplese (Frederieg, 1991) is produced from milk and/or egg protein by an internationally patented and blending process called Microparticulation. As proteins are heated, they coagulate under ordinary conditions, heat-coagulated proteins from large particles to gel, which feel rough in the mouth.

Precise blending or shearing in the micro-particulation process shapes the protein gel into spheroidal particles so small that tongue perceives them as fluid rather than individual particle. Since the protein is shaped into tiny particles below the perceptual threshold of the tongue, the fat substitute has richness and creaminess normally associated with fat. In addition, each gram of the fat substitute, which is hydrated protein (1.3 Kcal/g), will replace one gm of fat (9 Kcal/g). In addition to frozen desserts, the fat substitute is expected to be used in other dairy products such as yoghurt, cheese spread, cream cheese and sour cream. It has also application in oil-based products such as salad dressing and margarine. Because, it is made from proteins, the fat substitute will not be used in cooking oils or in food products that require frying or

Table 1. Calorie Comparison Between Simplese Prototype and Traditional Product

	Traditional	Simplese	Calories saved
Superpremium IC (4 fl.oz)	283	130	153
Yoghurt (8 oz)	139	100	39
Salad dressing (1 tbl.sb)	87	21	66
Mavonnaise (1 tbl sp)	99	30	69
Butter/Margarine (1 tbl sp)	36	8	28
Processed cheese spread (1 oz)	82	36	46
Cream cheese (1 oz)	99	45	54
Sour cream (1 tbl sp)	26	10	16

baking. The heat level in such applications would cause the ingredients to coagulate and loss its fat-like mouthful (Anon, 1988a).

TrailBlazer™ is also a protein-based fat substitute prepared from egg white and milk protein and is developed by a different process other than micro-particulation.

Another dairy-based fat replacer, unveiled at the 1996 IFT Annual Meeting, may be used to improve the taste, mouthful and nutritional value of low and non-fat food products called Yoghurt-tesse™, the ingredients of which are skim milk solids etc.

Recently, Simplesse has been used to make mozzarella cheese and this product when used for Pizza preparation has shown that under the extreme conditions used the colour, taste and stretch were not lost. Table-1 gives the calorie comparison of Simplesse and a traditional product (Anon, 1991a).

Whey Protein-based Fat Substitute

The denaturation of ultrafiltered whey proteins by controlled heat treatment gives a dried whey product, which is marketed as Dairy Lo. It is made from partially denatured sweet whey proteins of improved functionality (e.g., a controlled degree of viscosity, improved water binding) and its use at 2 to 5 % in dairy products contribute to desirable mouthfeel attributes. It is not suitable for use in products intended for processing at high temperature because of its controlled degree of denaturation (Anon, 1993).

Plant Protein-based Fat Substitute

A zein-based fat substitute is marketed under the trade name Lita™. It stimulates the sensory and physical characteristics of an o/w emulsion. This is due to the size of the protein microsphere, which has approximately same dimensions (0.3-3 µ) and shapes as oil droplets found in dairy cream

or other oil in water emulsion. Zein is naturally hydrophobic because of a high incidence of non-polar amino acids. It being natural, is finding application in various formulations where simple and other starch-based replacers are used (Anon, 1991c).

Synthetic Fat Substitute

Basically, a fat molecule consists of a glycerol moiety to which three fatty acids are attached. The physico-chemical and sensory properties of a fat mainly depend on the type of fatty acids, attached to the moiety. Its structural configuration can be altered to get the desired product with same functional property as that of fat but with a lower calorific value. The changes are mainly with respect to the substitution of glycerol or fatty acids, which leads to two varieties:

i) In this, the molecular backbone structure is so well designed that it preserves the functional properties of the fat but cannot be digested, e.g., olestra.

ii) The modification that is brought about with respect to the type of fatty acid attached to the glycerol backbone. In this case, the attached fatty acids groups cannot be completely digested

Basically, a fat molecule consists of a glycerol moiety to which three fatty acids are attached.

and/or are poorly absorbed, e.g., esterified propoxylated glycerols (EPGs). (Anon, 1991d)

Sucrose Polyester

Probably closest to a real low calorie fat or oil substitute are the sucrose polyesters. Such as

olestra, a mixture of hexa, hepta and octa esters of sucrose with naturally occurring fatty acids, principally from C₈ to C₁₀, is grouped under the collective name of sucrose polyester. The appearance, flavour, heat stability, flash point and shelf-life of olestra are similar to those of standard fat. Therefore, olestra may be used virtually wherever fats are used, even in the high temperature applications such as baking and deep-fat-frying.

Procter and Gamble reported results of extensive taste tests which indicated panelists were unable to distinguish food containing olestra from those containing only conventional fats. Olestra, however, differs from conventional fats in one important respect - It is not absorbed. It passes through the digestive system unchanged, contributing no calories to the products in which it is used. It has been used to partially or completely replace fats in frozen desserts, table spreads, salad dressing and cheese.

Esterified Propoxylated Glycerol (EPG)

EPG's are a new family of propylene oxide derivatives. The structure of EPG's is similar to that of natural fat. To produce the non-calorie triglyceride, glycerine is reacted with propylene oxide to form poly ether Polyol, which is esterified with a fatty acid or fatty acids. Preliminary digestibility studies have shown that EPG is resistant to enzymatic hydrolysis and that it can be substituted for fats and oils in products such as table spreads, frozen desserts, salad dressings and bakery products.

Polyglycerol Esters

These are obtained by the esterification of polyglycerol with fatty acids. The process involves two steps. Firstly, polymerization of glycerol is done in the presence of high temperature (230°C) and an alkaline catalyst, with removal of

water that is formed. The polyglycerol obtained is further reacted with fatty acids to get polyglycerol ester. In the course of replacing glycerol with polyglycerol, the resulting ester becomes more hydrophilic, i.e., more surface-active than mono or diglycerides. Their properties can be modified by controlling the parameters, like degree of polymerization, degree of esterification and choice of fatty acid used for esterification. A commercial product, Polyalda, is primarily being used to extend the functionality of the remaining fat. The application of polyglycerol ester relates to emulsified food products.

Polysiloxane

It is an organic derivative of silica bearing a linear polymeric structure. The type of polysiloxane depends on the organic radicals such as all methyl, or partly methyl and partially phenyl groups. These compounds are chemically inert, non-absorbable and claimed to be non-toxic. They maintain their viscosities over large range of temperature and are resistant to oxidation, hydrolysis and degradation.

Dialkyl dihexadecylmalonate (DDM)

A fatty alcohol ester of malonic and alkyl malonic acid, is being developed as fat substitute for high temperature application. DDM has been used to produce potato and tortilla chips. The DDM-soybean oil blend results in a 33% reduction in caloric and a 60% reduction in fat. Studies have shown that the synthetic fat substitute is minimally digested and that less than 0.1% is absorbed.

Trialkoxytricarballate (TATCA)

Tricalballi acid esterified with fatty alcohols, is being evaluated as an oil substitute. The ingredient has reportedly been used to produce acceptable margarine

and mayonnaise-type products and to have potential applications in any formulation in which vegetable oils are used.

Trialkoxycitrate (TAC)

It is similar to TATCA and is synthesized from oleyl alcohols. It is a colourless oil and is composed mainly of fatty alcohol esters of citric acid.

TAC does not have thermal stability similar to that of TATCA and therefore, it does not find applications in high temperature processed foods. It is claimed to be suitable for mayonnaise.

Medium Chain Triglycerides (MCTs)

**Nektalite™,
a fruit-based
ingredient
can be used as
substitute for milk
fat, butter and
casein-derived
products.**

Medium chain triglycerides are specially fats composed primarily of the saturated 8 to 10 carbon atom chain fatty acids-caprylic and capric, respectively. The stepwise process used in manufacture involves the hydrolysis of high grade vegetable oil, the fractionation of the resulting fatty acids to concentrate C₈ and C₁₀ fatty acids and subsequent esterification with glycerol to form triglyceride.

MCTs differ from regular fats and oils in two important ways: first MCTs are not metabolized through the gut like regular fats and oils but rather in the live, like carbohydrates. Thus, they are not deposited as depot fat but instead are burnt for energy.

Secondly, whereas regular fats and oils provide 9 Cal/g, MCTs provide 8.3 Cal/g - more than twice the amount of energy provided by glucose.

Since MCTs function similar to regular lipid vegetable oils, they can be substituted chiefly for liquid vegetable oils in most product formulations. MCTs are also ideal for incorporation into low or reduced calorie foods, such as salad dressing, baked goods, and frozen products due to their "reduced" caloric content when compared to regular vegetable oils (Megremis, 1991).

Combination Products

Consulting companies have been working on the applications of fat substitutes for many years. Their products are usually combination of the fat substitutes described above with or without the addition of independently developed components (Pszczola, 1996).

Prolestra, Nutrifat, Finesse fat substitutes have been offered. Prolestra is described as a source of polyester and protein composition with applications in ice cream, salad oils, mayonnaise, table spreads, sauces, snacks and baked products.

Nutrifat C (Anon, 1988b), PC, Instant PC and PC supreme have been introduced as a balanced blend of several hydrolyzed starches for upto 50% fat replacement: same as Nutrifat C with proteins and polysaccharides added for upto 81% fat replacement: like Nutrifat C but requires no heating.

Colestra™, is the name given to low calorie, olestra type fat substitute.

Prolo 11 (Anon, 1993), fat mimetic, consisting of cultured, non-fat milk, may be used in milk shakes, frozen yoghurt and ice cream. The ingredient is said to mimic the smooth, creamy mouth-feel of butterfat.

Keystone 3100, stabilizer system functions as an alternate ingredient to fat when formulating low and no-fat dairy products, such as dairy-based drinks, frozen yoghurt and ice cream. Available in dry form, the system is designed for rapid hydration and consists of milk proteins, guar gum, lecithin, xanthan gum and carragenan (Pszczola, 1996).

Nektalite™, a fruit-based ingredient can be used as substitute for milk fat, butter and casein-derived products. Described as a fat mimetic, the no-fat, no-cholesterol ingredient provides a creamy texture for use in ice-cream, cakes, cookies, muffins and other products. It is said to be suitable as a bulking agent and offers binding, aeration and suspension properties. It contains dietary fibre and is high in fruit carbohydrate.

N-Flate is a blend of non-fat milk solids, emulsifier, modified food starch and guar for use in low-fat cake mixes at 6 to 8 % levels.

Ultrafreeze 400, a blend for use in low-fat frozen desserts at low levels of 0.75 to 1.5%, consists of modified starch (Food starch), vegetable proteins and corn syrup solids.

Conclusion

Although, ample work has been carried out with vast information having been generated on fat replacers, studies on the toxicological and analytical aspects have not been carried out extensively and particularly in the Indian context, people of a very restricted or limited category have knowledge about fat replacers. However, in the recent past, attempts have been made to throw

light on reduced fat foods such as for Amul Lite™ for which responses have been good.

Finally, it should be stressed that there is a need to develop fat replacer of versatile type, which can be used in a number of food products. In short, single fat-replacer should be able to work for a number of food types.

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Prospects for Bioproduction of Food Flavours

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Abstract

Flavours find a wide range of applications in the food, cosmetic and pharmaceutical industries. Extensive studies have been carried out on the microbial biosynthetic pathways for the production of flavours in the past decade. However, the commercial exploitation of only few processes has been possible currently. The present article delineates the various biotechnological processes involving microorganisms, their enzymes and their bioconversion pathways for the production of food flavours. The plant and cell tissue culture techniques, which are catching up importance for flavour production, are also described.

Introduction

Flavours play an important role in the food, cosmetic, feed and pharmaceutical industries. Among the food systems, flavour is a unique attribute which determines its acceptability. Flavour can be described as the combined perception of taste, smell and mouthfeel (Hatchwell, 1994). In the recent past, many of the food products containing synthetic flavours were often avoided, because the consumers considered these compounds as toxic or harmful to their health. Even the drawbacks of such chemical processes are the formation of undesirable mixture of isomers and the growing aversion of the consumer towards the addition of such

chemicals to his food, cosmetics and other household products.

Flavours play an important role in the food, cosmetic, feed and pharmaceutical industries.

There has also been an increased consumer response towards 'natural' ingredient(s) in food systems, which are used for

Microbiological processes are considered to be a better option for the production of flavours with respect to conditions required for the optimization of process and the cost.

the manufacture of clean label products, containing no artificial additives (Anon, 1995). This caused a renewed interest among

flavour companies to direct their attention towards flavour compounds of biological origin, so called natural - or bio-flavours. In view of this, focus is now drawn towards the utilization of biotechnological applications such as microbial genetics, fermentations and enzymatic processes for the flavour production. The present article discusses the various approaches employed for the production of flavours using microorganisms and their enzymes, the bioconversion processes for flavour compound synthesis and the plant cell and tissue culture techniques.

Microbiological Process

Microbiological processes are considered to be a better option for the production of flavours with respect to conditions required for the optimization of process and the cost. These processes can take two routes (Welsh *et al.*, 1989) :

(a) biosynthesis of a specific compound by metabolizing cells, and (b) biotransformation or bioconversion - which involves modification of chemical substrate by microbial cells.

Most of the microbial flavour compounds are secondary metabolites. They are produced in low concentrations and have low flavour threshold values of the above two routes, *de novo* biosyn-

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thetic pathway results in lesser yields and is economical whereas, biotransformations are cost-effective and finds widespread industrial applications. The major microbial flavour sources include bacteria, yeasts and filamentous fungi. Each has its own significance in the production of flavour. Flavour production is not an easy task, but it involves complex interactions among various biological and physio-chemical constituents, which give rise to compounds imparting flavour or act as flavour potentiators.

Some of the most common

flavour compounds produced from microbial sources are described below :

Terpenes are the primary flavour and fragrance chemicals found in the essential oils and higher plants.

Terpenes

Terpenes are the primary flavour and fragrance chemicals found in the essential oils and higher plants. Significant among these are the mono -and sesquiterpenoids. Terpenes are a diverse group of compounds, which have 5 carbon isoprene (2-methyl-1,3 butadiene) units in their basic structure. The number of isoprene units determine the type of terpene.

The terpene flavour compounds are produced by a variety of microorganisms (Table 1) and

Table 1. Microbially Produced Terpenes (Welsh *et al.*, 1989)

Microbe	Terpenes
<i>Ambrosiozyma cicatricosa</i>	Citronellol, geraniol, linalool
<i>A. monospora</i>	Citronellol, geraniol, α -terpineol, linalool
<i>Ascoidea hylecocti</i>	Citronellol, linalool, nerol, α -terpineol, citronellal, limonene, myrcene, citronellyl acetate, plus 14 other minor terpenoids
<i>Ceratocystis coerulescens</i>	Citronellol, geraniol, linalool, nerol, α -terpineol, geranyl acetate, citronellyl acetate, neryl acetate, α -terpinyl acetate, nerolidol, di-and tetrahydro-nerolidol, farnesol, 2,3-dihydro-6- <i>trans</i> -farnesol and its acetate
<i>C. fimbriata</i>	Citronellol, geraniol, α -terpineol, linalool
<i>C. moniliformis</i>	Citronellol, geraniol, α -terpineol, linalool, nerol, geraniol, neral, geranyl acetate, citronellyl acetate
<i>C. variopora</i>	-do-
<i>C. virescens</i>	-do- plus neryl acetate
<i>Eremothecium ashbyi</i>	Geraniol, linalool, nerol
<i>Ischnoderma benzoinum</i>	Linalool
<i>Kloeckera apiculata</i>	Linalool, α -terpineol, limonene, farnesol, β -myrcene
<i>Kluyveromyces lactis</i>	Citronellol, geraniol, linalool
<i>Lentinus lepideus</i>	Cadinene, murolene, several sesquiterpenes
<i>Metschnikowia pulcherrima</i>	Linalool, α -terpineol, limonene, farnesol, β -myrcene
<i>Penicillium decumbens</i>	Nerolidol, thujopsene
<i>Phellinus igniarius</i>	Linalool, α -pinene
<i>P. tremulae</i>	-do-
<i>Pleurotus euosmus</i>	Linalool, <i>cis</i> - and <i>trans</i> -linalool oxides
<i>Polyporus durus</i>	Sesquiterpenes
<i>Saccharomyces fermentati</i>	Linalool, <i>Cis</i> and <i>trans</i> -nerolidol, <i>trans</i> -farnesol
<i>S. rosei</i>	Linalool, farnesol, β -myrcene
<i>Torulopsis stellata</i>	Citronellol, farnesol
<i>Trametes odorata</i>	Citronellol, geraniol, nerol, D-limonene
<i>Trichothecium roseum</i>	Citronellol, nerol, linalool, α - and β -terpineol
<i>Trametes odorata</i>	Citronellol, geraniol, nerol, D-limonene
<i>Trichothecium roseum</i>	Citronellol, nerol, linalool, α - and β -terpineol, citronellyl acetate, geranyl acetate, linalyl acetate, nerolidol

primarily by ascomycetes and basidiomycetes. With certain exceptions, yeasts have been shown to produce only a small quantity of terpenes. However, for industrial applications yeasts are preferred to filamentous fungi, because they do not cause rheological problems and also exhibit homogeneous growth.

Pseudomonads possess the ability to metabolize terpenes of which, *Pseudomonas putida* NRRL B18040 (PP.U2.9) was found responsible for the transformation of geraniol to a novel compound, 6-methyl-5-heptene-2-one (Vandenbergh, 1989). This product was described to have a pleasant, fruity odour and suitable for use in foods. Microorganisms *per se* are poor sources of terpenes, but they can be used to perform biotransformation of natural to more marketable forms. Only a few reports exist on bacteria capable of producing terpenes of

which, *Pseudomonas putida* or *Celulomonas turbata* was employed in the production of L-menthol from L-menthone, a compound, which predominates in peppermint plant during floral initiation. In another method, the mechanism of stereospecificity of microbial enzyme was used to convert isomeric mixture of DL-methyl ester to L-menthol (Romero, 1992).

In another process involving a yeast, *Cryptococcus albidus* ATCC 20918 transformed a powdered sclareol preparation into a lactonized diterpenoid called scalareolide. This compound found commercial application in tobacco and food flavourings and as a synthetic substrate for the preparation of a series of ambra odorants in perfumery (Farbood *et al.*, 1990).

Alkyl Pyrazines

Pyrazines are a diverse group of heterocyclic nitrogen con-

taining compounds. They contribute nutty or roasty flavour in high temperature processed foods. There is relatively less information on the microbial production of pyrazines. However, among alkyl pyrazines, tetra methyl pyrazine has been reported to be produced by *Bacillus subtilis* (Kosuge and Kamiya, 1962) and *Corynebacterium glutamicum* (Demain *et al.*, 1967). Another alkyl pyrazine, 2-methoxy-3-isopropyl pyrazine (MIPP), has been found to be produced by two *Pseudomonas* species like *Ps. perolens* and *Ps. taetrolens*, which are related to the production of musty flavour, a potato flavour defect in food products (Morgan, 1976).

Various types of pyrazines were produced by *Lactobacillus helveticus*, when grown on whey permeate supplemented with filter-sterilized amino acids. These included a pyrazine with formaldehyde in the second position,

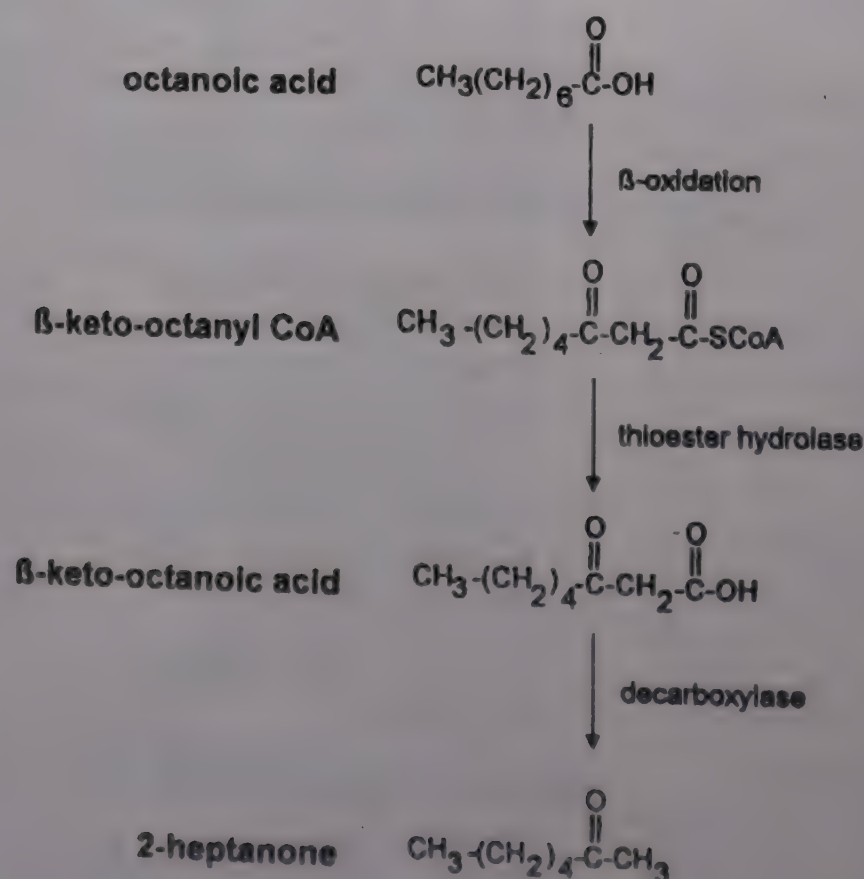


Fig. 1. Biosynthesis of the ketone, 2-heptanone (Murray *et al.*, 1988)

alkyl pyrazines and alkoxy pyrazines. The quantities of pyrazines produced were so small and their mass spectra too impure, made it difficult to identify the types of isomers present. However, this work reinforced the theory that pyrazines were produced by the cheese organisms (Kowalewska *et al.*, 1985). In another study, *Penicillium caseicolum*, a surface organism used to ripen Camembert and Brie cheeses, also produced 2-methoxy-3-isopropyl pyrazine in a defined medium (Kinderlerer, 1989).

Esters

Esters of both aliphatic and aromatic types contribute to flavour production in all fruits and in many other foodstuffs. Esters are produced by a wide variety of microorganisms including fungi, yeasts and bacteria. Their amounts of production depend upon the microbial species. Two main pathways can result in the formation of esters :

1. direct esterification of an organic acid with alcohol and
2. by reaction of alcohols and acetyl CoA.

Direct esterification of alcohol and acids is mainly observed in case of bacteria and filamentous fungi. This type of process occurs in dairy products due to microbiological production of ethyl butyrate and ethyl hexanoate by several genera of lactic acid bacteria. Another esterification process due to water soluble, mycelium bound phospholipases, has been exhibited by *Rhizopus arrhizus* and *Mucor javanicus*.

In yeasts, the process of esterification occurs by the use of an alcohol and acetyl CoA. The fermentation parameters, which affect the ester formation, are mainly the medium composition and oxygen. Under anaerobic conditions, yeasts have shown a specific requirement of unsaturated fatty acids, which stimulate their growth (Mattey, 1992).

Carbonyls

They form one of the most important group of flavour compounds and are characterized by the presence of carbonyl groups (C=O). They mainly comprise ketones, diketones and aldehydes.

Esters of both aliphatic and aromatic types contribute to flavour production in all fruits and in many other foodstuffs.

Ketones

Ketones are mainly responsible for cheese flavours, especially in mold ripened cheeses. A pathway for the biosynthesis of ketone is shown in the Fig.1. In general, *Penicillium* sp. produces lipases, which govern the rate of fatty acid release. Subsequently, the fatty

Ketones are mainly responsible for cheese flavours, especially in mold ripened cheeses.

acid undergoes beta-oxidation followed by addition of an acyl group and decarboxylation to form 2-alkanones, one carbon shorter than the original fatty acid. The odd number C₅ to C₁₁ and alkanones along with constituent-free fatty acids and secondary alcohols, give *Penicillium* ripened cheeses their distinctive flavour (Kinsella and Hwang, 1976).

Presently, only *Penicillium*

species find their use in the production of ketone flavours. The ability to produce low concentration of 2-alkanones has been reported in both yeasts and bacteria (Hou *et al.*, 1980). *Aureobasidium pullulans* can produce pentan-2-one, heptan-2-one, nonan-2-one and undecan-2-one, which are suitable for use in food flavours (Grinsven *et al.*, 1991). Acetophenone, a naturally occurring ketone in honey, plums and strawberries can be produced by the bioconversion of cinnamic acid by *Pseudomonads* (Hilton and Cain, 1990).

Diketones

The most important diketone is diacetyl (2,3 butanedione), which imparts buttery and nut-like flavour attributes to a variety of dairy products. In a good quality cheese, its level may vary and usually be approximately 0.05 mg/100g (Calbert and Price, 1949). However, higher levels are not suitable for cheddar flavour. On the other hand, in butter, high levels of diacetyl (0.1 to 0.2 mg/100g), has been proven to be desirable through sensory evaluation tests (Pette, 1949). However, in some cases, it is undesirable and causes flavour defects in wine, beer, etc. (Russel and Stewart, 1992). The microbial formation of diacetyl is brought about by citrate utilization. There are two mechanisms involved in diacetyl production :

- a. Excess pyruvate is decarboxylated to active acetaldehyde (TPP, acetaldehyde-thiamine pyrophosphate complex), which then condenses with acetyl CoA followed by cleavage of TPP and CoA-SH to form diacetyl and
- b. In the second mechanism, condensation of pyruvate and acetyl and CoA takes place to form acetolactate, which upon removal of CO₂ gives rise to diacetyl or a related component, acetoin.

Diacetyl production by lactic starter bacteria is mainly dependent upon the citrate level in milk

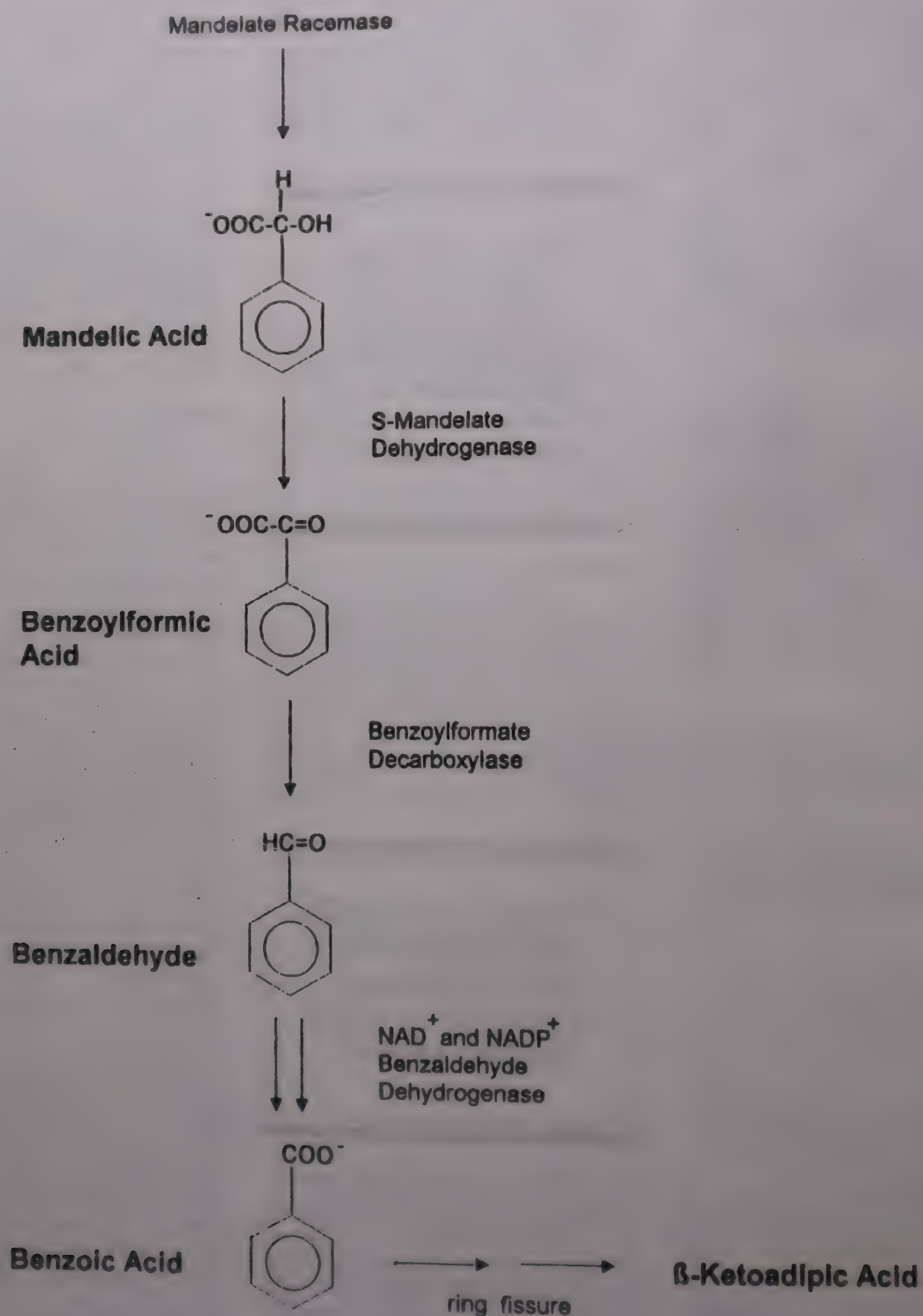


Fig. 2. Pathway for the degradation of mandelic acid in *Pseudomonas putida* (Tsou et al., 1990). The first step in the pathway, catalysed by mandelate racemase, converts enantiomeric forms to S-mandelic acid.

and the presence of plasmids which code for citrate permease enzyme, resulting in citrate utilization. The above factors can be controlled by supplementing the medium with citrate and also by the use of recombinant DNA (rDNA) techniques in which the genetic determinants of citrate permease are incorporated into the chromosomes and stabilized by a process called integration. This can be made possible by the development of functional integration vectors for lactococci (Romero and Klaenhammer, 1992) and the cloning of citrate permease gene (Sesma *et al.*, 1990).

For the optimum production of diacetyl, it is essential to control the physico-chemical fermentation conditions. For example, aeration results in high redox potential and diacetyl formation. Similarly, low pH also stimulates the formation of diacetyl. In one of the patented processes, the addition of glycerol or sucrose as humectant lowered the water activity, which resulted

in an increase in diacetyl production. The highest diacetyl concentration reached was 10.5 mg/L (Troller, 1981).

Natural diacetyl can be obtained from the distillates of lactic starter cultures (Sharpell, 1985). In some of the fermented milk products like shrikhand, a large

Aldehydes are also valued high in food industry for their flavour and aroma producing capabilities.

proportion of flavour compounds like diacetyl are lost during whey drainage, which can be compensated by blending the product with flavour distillates of the whey (Rao *et al.*, 1994).

Aldehydes

Aldehydes are also valued high in food industry for their flavour and aroma producing capabilities. In general, C₂ to C₇ aliphatic aldehydes are volatiles and characterised by unpleasant odours, while C₈-C₁₃, because of their increasing molecular weight, are considered more pleasant. Aldehydes are usually synthesized by microbes as intermediates in the formation of alcohols by decarboxylation of keto acids. Benzaldehyde, vanillin and acetaldehyde are a few examples, which have gained importance for industrial pathway.

Acetaldehyde is one of the important components, contributing to the characteristic flavour of yoghurt, when it is formed by lactic acid fermentation. High levels of acetaldehyde could be important for improving the starter cultures intended for yoghurt production. Acetaldehyde production has also been reported from yeasts like *Zymomonas mobilis*

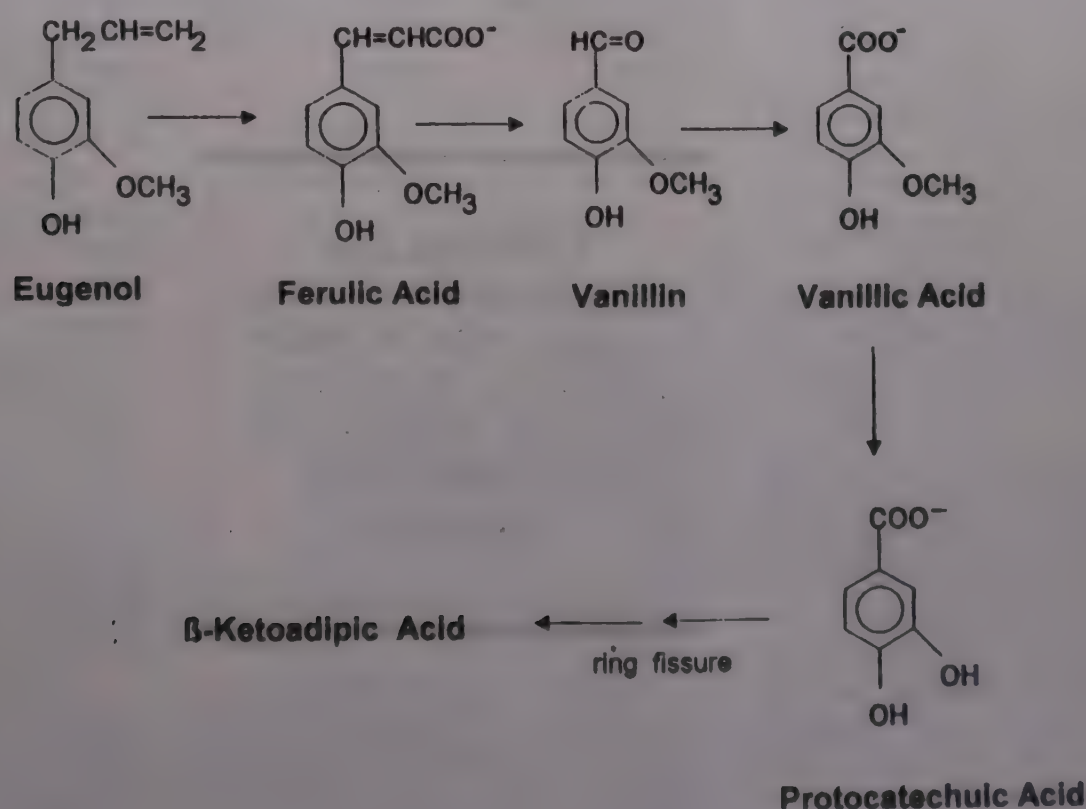


Fig. 3. Proposed pathway for the degradation of eugenol by a *Corynebacterium* species (Tadasa, 1977)

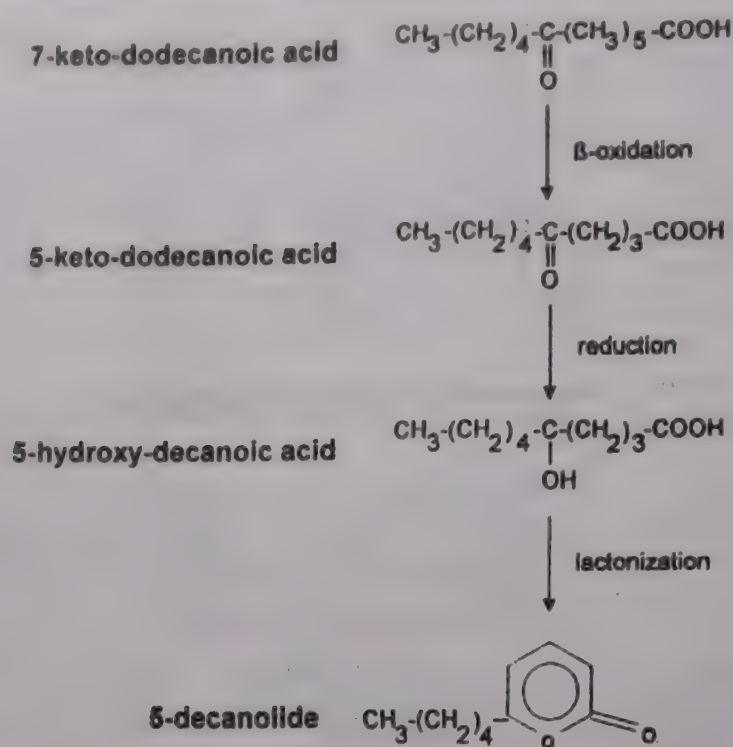


Fig. 4. Lactone biosynthesis (Murray et al., 1988)

(Ishikawa and Tanaka, 1992) and *Saccharomyces cerevisiae* (Romano et al., 1994).

Another aldehyde of great demand is the benzaldehyde, which finds application as an oil-of-bitter almond substitute for almond or cherry flavourings. In the early stages, before the strong demand for natural products developed, the bulk of the cherry-type flavours used in the food and beverages were synthetic. However, attention was drawn towards benzaldehyde, when in France, it was discovered that the major portion of it was derived from toluene. This incident, along with the stronger consumer demand for natural products, forced many flavour makers to seek alternate process routes to natural benzaldehyde. One of the ideal routes to benzaldehyde would be the *de novo* production from simple, readily available sugars like glucose, sucrose, etc. or at least the biotransformation of a suitable natural precursor to the aldehyde.

A pathway for benzaldehyde production from mandelic acid in *Pseudomonas putida* (Tsou et

al., 1990) is shown in Fig.2. This method has a high potential for industrial use. Biotechnological mutagenic techniques can be used to inactivate benzaldehyde dehydrogenases, which would result in accumulation of benzaldehyde.

Lactones are characteristic flavour compounds in dairy products, fruits like peaches, apricot, etc. and other food flavours.

Apart from acetaldehyde, there are a number of other natural aldehydes that have significant commercial potential. Vanillin (vanillic aldehyde or 4-hydroxy-3-methoxybenzaldehyde) is one of the most important and common flavour chemicals and is widely

used in a broad range of flavours. Natural vanillin is obtained from the beans of vanilla orchid. Most of the vanillin available is derived synthetically from petrochemicals such as guaiacol, but also from lignin, a waste by-product of wood pulp industry (Clark, 1990). Vanillin is also a metabolic intermediate in the biodegradation of a variety of natural products including eugenol and ferulic acid (Toms and Wood, 1970; Tadasa and Kayanara, 1983). In a novel method, aromatic amino acids were deaminated by *Proteus vulgaris* (CMCC 2840) to the corresponding phenylpyruvic acids, which on further using a mild caustic, were converted to the corresponding aldehydes. This produced vanillin from methoxytyrosine and benzaldehyde from phenylalanine (Casey and Dobb, 1992).

However, eugenol, an important flavour metabolite and main constituent of clove oil, can be degraded to vanillin (Fig. 3). Ferulic acid may act as a substrate for production of vanillin. It is a metabolic intermediate in lignin metabolism and has also been

shown to be used by *Bacillus subtilis* (Gurujeyalakshmi and Mahadevan, 1987).

Lactones

Lactones are characteristic flavour compounds in dairy products, fruits like peaches, apricot, etc. and other food flavours. A number of microorganisms produce lactones, but yields are generally low, which limit their commercial exploitation. Ricinoleic acid is the major fatty acid present in castor oil. Its concentration is upto 80%. *Candida* spp. can be used for the bioconversion of ricinoleic acid to 4-decanolide (Okui *et al.*, 1963).

These microorganisms were capable of degrading the castor oil triglycerides to release ricinoleic acid, which is further degraded to 4-hydroxydecanoic acid by β -oxidation. The further conversion of this hydroxy acid to 4-decanolide is through heat and acid treatments. Lactone was purified by solvent extraction and

yields were found to be 5 g/L (Farbood and Willis, 1983).

In case of *Pichia guilliermondii*, methyl ricinoleate is the inducer of β -oxidation and also a probable substrate for γ -decalactone (Belin *et al.*, 1993). *Sporobolomyces odoratus* has also been reported to produce γ -decalactone. By the addition of 3% castor oil, an yield of 8.62 mg/L of γ -decalactone was obtained after 24 h of fermentation (Chou and Lee, 1994). Table 2 provides a comprehensive list of microorganisms and the type of lactones synthesized. Their mechanism of formation is illustrated in Fig. 4.

Alcohols

Barring a few (cis-3-hexenol and octene-3-ol), alcohols do not play much role as flavourants. Their significance is rather indirect, where they may act as precursors for other flavour compounds like aldehydes and esters. The C₈ alcohols like octan-3-ol, octa-1-en-3-ol etc. give rise to mushroom

flavour. The production of these C₈ alcohols is common in fungi like *Trichothecium roseum*, *Penicillium caseicolum* and *Penicillium camemberti* (Karahandian *et al.*, 1985). Their production has been suggested to be the result of dehydrogenase activity on corresponding methyl ketones. The mechanism of formation of aldehydes and alcohols from amino acids by *Streptococcus lactis* var. *maltigenes* is shown in Fig. 5 (Seitz, 1990).

The levels of isobutanol and isoamyl alcohol play a major role in contributing flavour characteristics during bread making. However, production of isobutanol by Bakers' yeast mutants is desirable for giving the bread its characteristic flavour, while production of isoamyl alcohol is not favourable. The productions of isobutanol and isoamyl alcohol are related to the inhibition of the key enzymes, acetohydroxy acid synthase and α -isopropyl malate synthase, respectively (Watanabe *et al.*,

Table 2. Microbially Produced Lactones

Microbe	Lactones
<i>Candida globiformis</i>	5-decanolide
<i>C. pseudotropicalis</i>	5-decanolide
<i>Ceratocystis moniliformis</i>	4- and 5-decanolide
<i>Cladosporium butyri</i>	5-decanolide
<i>Ischnoderma benzoinum</i>	4-butanolide, 4-pentanolide, 4-hexanolide, 2-hexen-4-olide, 4-heptanolide, 2-hepten-4-olide, 4-octanolide, 2-octen-4-olide
<i>Pityrosporum</i> sp.	4-hexanolide, 4-heptanolide, 4-octanolide, 4-nonanolide, 4-decanolide, 4-dodecanolide
<i>Polyporus durus</i>	4-butanolide, 4-pentanolide, 3-penten-4-olide 5-hexen-4-olide, 2-hexan-4-olide, 2-hepten-4-olide, 4-hexanolide, 5-hexanolide, 2-5- and 6-octen-4-olide, 4-octanolide, 2-nonen-4-olide, 2-decen-4-decanolide, 4-methoxy-6-methyl-2H-pyran-2-one
<i>Saccharomyces cerevisiae</i>	5-decanolide
<i>S. fermenti</i>	4-butanolide, 5-ketohexan-4-olide
<i>S. fragilis</i>	5-decanolide
<i>Sporobolomyces</i> sp.	5-decanolide, 5-decanolide, cis-7decen-5-olide cis-6-dodecen-4-one
<i>Trichoderma viride</i>	6-(pent-1-enyl)- α -pyrone, 6-pentyl- α -pyrone

Source : Murray and Duff (1991).

1990). Moreover, the precursors for these alcohols are α -ketoisovalerate and α -ketoisocaproate, respectively (Fukuda *et al.*, 1990). *Zygosaccharomyces fermentati* also produces these alcohols and are responsible for the aroma and taste of wine (Suzzi and Romano, 1993).

Acids

Acids also contribute to complex aroma and accentuate flavour characteristics. In general, low molecular weight short chain fatty acids have unpleasant and pungent odours, while high molecular weight acids have a low flavour impact. Acetic and butyric acids are used as single flavourants. However, acetic acid is the most important flavouring agent for sour and acidic taste of foods (Belitz and Grosch, 1987). The microbial production of acids occurs in different ways, e.g. lactic acid and the C₁ to C₅ aliphatic acid series are primarily the end products of fermentation. Higher chain saturated fatty acids i.e., from C₆ to C₁₈ are produced by classical fatty acid synthesis and from these, by a oxygen dependent desaturase reaction, unsaturated fatty acids are formed (Berry and Watson, 1987). Isoacids are derived from amino acid biosynthesis via the Strickland reaction (Britz and Wilkinson, 1982). Other free fatty acids are obtained as a result of lipase action.

Acids like propionic and acetic form an important component of Swiss and Emmental cheeses. In the production of Swiss cheese, *Streptococcus thermophilus*, *L. helveticus* or *L. lactis* may be used as a starter culture to produce lactic acid. The residual sugar and lactic acid are then fermented by *Propionibacterium freudenreichii* (*P. shermanii*) to form propionic acid, acetic acid and CO₂.

Filamentous fungi produce organic acids, which serve as an acidulant in food industry and are employed to enhance or modify

flavour. Citric acid is one such flavour metabolite produced by *Aspergillus niger* (Mattey, 1992). It is used along with other organic acids like malic, fumaric or lactic acid to produce a desired flavour in beverages.

Kojic acid [5-hydroxy-2-(hydroxy methyl)-4-pyrone] has application for the synthesis of

Acids also contribute to complex aroma and accentuate flavour characteristics.

maltol and ethyl maltol, which is used as a flavour enhancer in foods (LeBlanc and Akers, 1989). Kojic acid is obtained by fermentation of *Aspergillus oryzae* grown on glucose and then it is chemically modified to yield maltol or ethyl maltol.

The major flavour potentiators, which are currently being used are monosodium glutamate (MSG), inosine monophosphate (IMP) and guanosine monophosphate (GMP).

Flavour Potentiators

These are chemicals that when added to food enhance the flavour in foods. The major

flavour potentiators, which are currently being used are monosodium glutamate (MSG), inosine monophosphate (IMP) and guanosine monophosphate (GMP). Among these, MSG is an important flavour potentiator finding wide usage in a variety of foods. Its L-isomer is only active. *Corynebacterium glutamicum* is the most common microbial source exploited for the production of MSG. This microorganism produces sufficient quantities (30-50 g/L) of L-glutamic acid in a fermentation time of 72 h (Margalith, 1981). Ajinomoto, a Japanese company is a leading producer of MSG. In India, MSG is being commercially used in most of the food preparations.

Microorganisms like yeasts and bacteria are capable of causing bioconversions of nucleic acids to 5'-nucleotides. Yeasts are still considered to be the organisms of choice due to high purity and quantity of end product formation. Various flavour enhancers show synergistic behaviour among themselves to produce enhanced taste intensity (Nagodawithana, 1992).

Enzymatic Synthesis

Enzymes have wide applications in food industry for their multifunctional roles. The rheological and organoleptic attributes are important and they determine the overall quality and consumer acceptance of the product. They are particularly useful in cheese, bakery and wine industries. The flavour production is one such area, where potential of enzymatic conversion has been utilized extensively. Enzyme-mediated bioconversions are performed at more moderate temperatures, pressures and pH than similar chemical synthesis. These biocatalysts can produce biotransformations that are difficult to emulate by chemical synthesis, but their slow rate of oxidation, low yield and high cost of operation are some of the factors, which sometimes make their

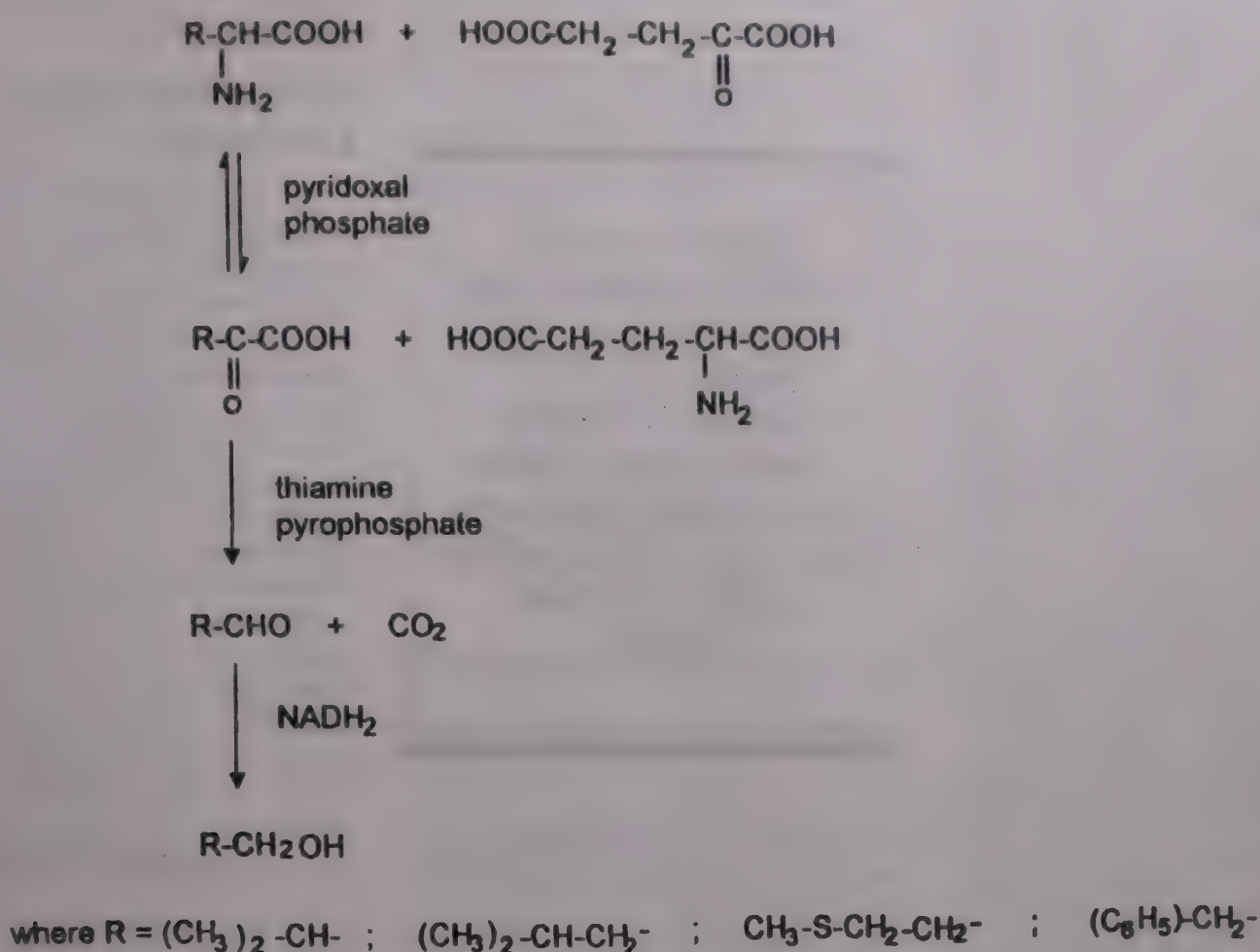


Fig. 5. Mechanism of formation of aldehydes and alcohols from amino acids by *Streptomyces lactis var multigenes* (Seitz, 1990)

isolation difficult.

With respect to flavour development, hydrolases and enzymes involving redox reactions or oxidoreductases are very important. Another factor which needs emphasis is the medium conditions like pH, temperature, type of solvent system, etc.

Hydrolases

Hydrolases like lipases, proteases, glucosidases act on fat, proteins, carbohydrates and hydrolyse them to their respective components. They also perform synthetic or preparatory reactions such as esterification, transesterification, lactonization and hydrolysis and are substrate specific. Manipulation of reaction medium can be done to favour the process, which results in the production of flavour metabolites.

Lipases

The lipases (acyl glycerol hydrolases, EC 3.1.1.3) catalyses the hydrolysis of fats, which are elaborated by microorganisms present or growing in raw materials used in the production of certain foods. The localised production of microbial lipases in food systems is necessary for flavour development and textural changes to make the food palatable and acceptable. In dairy products, lipases are very important in the production of flavour in products like cheese, ghee, butter oil, etc.

Lipases are produced by a variety of microorganisms like *Penicillium roqueforti*, *P. camemberti*, *Geotrichum candidum*, *Candida mycoderma*, etc. The short chain fatty acids, especially of 4-8 carbon atoms are responsible for the peppery taste of mold ripened cheeses.

Though, lipolytic activity of lactic and propionic acid cheese flora is very low, mesophilic streptococci and leuconostoc bacteria can be considered more active than lactobacilli and *S. thermophilus* (Searies *et al.*, 1970). Lipases from filamentous fungi like *Rhizomucor miehei*, *Penicillium candidum*, *P. roquefortii* and *Aspergillus oryzae*. also act as source of exogenous enzymes (Bigelis, 1992).

Apart from dairy products, lipases also contribute significantly to the flavour of other food products. During ripening of Italian sausages, lipolytic micrococci and lactobacilli species play an important role in flavour development (Seitz, 1974). Similarly, in various other food products, lipases have been used to perform enantiospecific hydrolysis and esterification to yield flavour metabolites. Lipases have also been

used to accelerate the flavour development and biochemical changes in Cheddar and Gouda cheese (Kanawjia and Singh, 1988, 1990a; Rajesh and Kanawjia, 1990; Rajesh *et al.*, 1991).

Proteases

Bacterial and fungal protease are important in the production of flavour in dairy foods along with other food products like soy sauce, miso, natto and fish sauces. They bring about the hydrolysis of proteins to peptides and amino acids. With the proper choice of the protein source and control in the process of hydrolysis, the flavour characteristics of the product can be tailored to produce desirable flavour attributes. However, the main drawback with enzyme hydrolysed protein products is the development of bitterness, which is as a result of high level of

hydrophobic amino acids at the N-terminal of the remaining peptide. In a similar way, yeast autolysates are produced by the use of the cell's endogenous en-

Bacterial and fungal protease are important in the production of flavour in dairy foods along with other food products like soy sauce, miso, natto and fish sauces.

zymes. Proteases have been utilised for the quick flavour, body and texture formation in Cheddar

and Gouda cheeses (Kanawjia and Singh, 1988, 1990b; Rajesh and Kanawjia, 1990).

Galactosidases/ Lactases

β -galactosidase catalyses hydrolysis of lactose to glucose and galactose. The treatment of cheese milk with β -galactosidase resulted in the lowering of manufacturing time for cheddar cheese. The flavour, body and texture of the resulting cheese were improved and the ripening was accelerated by approx. 50% (Thompson and Bower, 1976; Marschke and Dulley, 1978). The application of partially lactose hydrolysed cow's milk has been used for rapid development of flavour and body in some varieties of cheese (El-Soda, 1986). In one of the studies carried out in our laboratory by using partially lactose hydrolysed buffalo milk

CARBOHYDRATES, AMINO ACIDS, ETC.

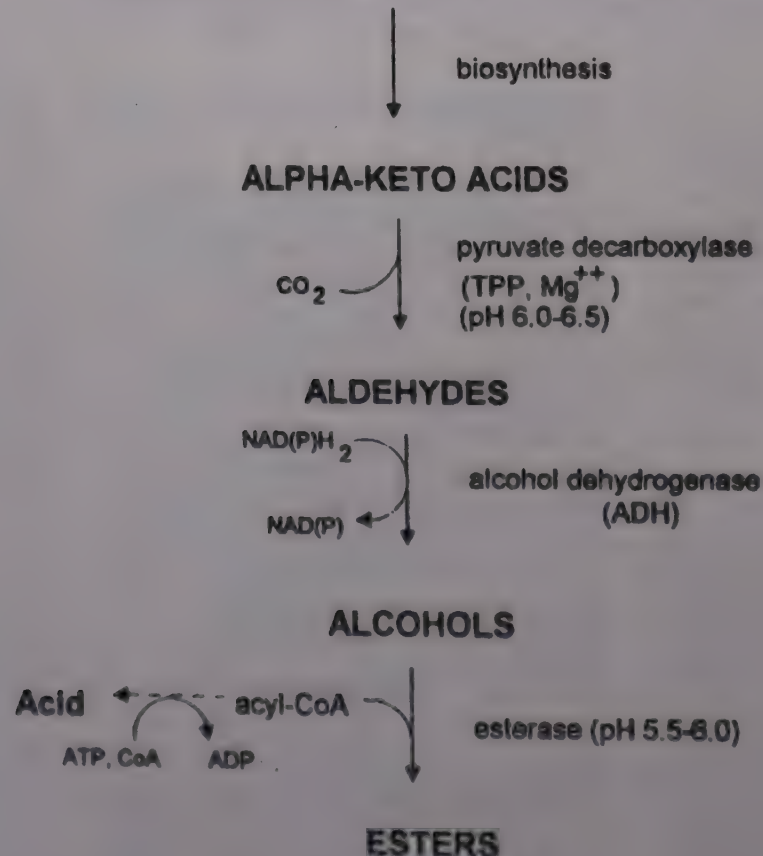


Fig. 6. Biosynthetic pathway for ester production in strawberry fruits (Hong *et al.*, 1990)

resulted in rapid flavour and body and texture formation during the ripening of cheddar cheese (Kanawjia and Singh, 1991).

Redox Enzymes (Oxidoreductases)

These catalyse a change in the oxidation state of the substrate. They require a co-factor, which are usually small molecular weight organic or inorganic groups. However, their industrial applications are limited, because of their dependence on co-factor for the action which makes the conversion costly. The various co-factors include metal ions, pyridoxal, biotin, ATP, FAD, NAD, etc. The two important redox enzymes, alcohol dehydrogenase and alcohol oxidase, perform the oxidation of aliphatic alcohols to their respective aldehydes.

Plant Tissue Culture

Plant tissue culture (PTC) is a technique that allows plant cells to be grown in solid or liquid media, like microorganisms in a laboratory. It involves establishing cultures of plant cells that are obtained from any part of the plant because of their totipotency. These find application for specific practical purposes like production of secondary metabolites in a higher yield than typically obtained in plants and the development of 'unique' chemicals. For both these applications, plant cells can be modified by using various techniques:

1. Mutagenesis;
2. Somatic variations;
3. Gametoclonal variations;
4. Recombinant DNA, and
5. Protoplast fusion.

The use of other modern biotechnological techniques like immobilization and the advanced fermentation processes along with the above can improve the performance of the process.

In PTC, secondary metabolites of interest are rarely produced by undifferentiated callus and cell suspension cultures. In this

regard, to induce flavour production by suspension cultures, several manipulation techniques have been employed like manipulation of culture medium composition, environmental fac-

Plant tissue culture (PTC) is a technique that allows plant cells to be grown in solid or liquid media, like microorganisms in a laboratory.

tors, addition of exogenous elicitors and induction of cell differentiation.

Strawberry plant (*Fragaria ananassais*) is considered to be most popular in foods, which have been exploited by plant tissue cul-

The development of novel and cheap production processes, such as solid-state fermentation may help to overcome some of the current limitations of microbial flavour production and also widen the spectrum of bioproduction of such compounds.

ture for flavour production in food systems. There are over 200 volatile compounds that have been identified in strawberry so far. These constitute majority esters, organic acids, carbonyls, alcohols,

lactones and furans (Hong *et al.*, 1990). Fig. 6 illustrates the schematic pathway for the production of esters in strawberry.

In one of the studies, the supplementation of liquid suspension culture system with short chain fatty acids and α -keto acids as precursors led to the formation of ethyl butyrate and butyl butyrate, while supplementation with α -keto valerate formed butanal and butanol. However, in case of unsupplemented or heat-treated suspension cultures, no aroma compound production was observed. Various enzymes like esterase, decarboxylase and alcohol dehydrogenase have been implicated in flavour production in strawberry cell cultures (Hong *et al.*, 1990).

In addition to strawberry production, the PTC technique has been exploited for the production of various other food flavours from apple (Kouider *et al.*, 1984), grape (Yamakawa *et al.*, 1983), pineapple (Casale and de Garcia, 1984) and raspberry (Borgman and Mudge, 1984). Vanillin flavours have also been produced by culturing callus cells derived from vegetative vanilla tissue and later moved to a reactor. After stimulating the culture with nutrients, the product is removed and purified (Knuth and Sahai, 1991). However, because of some inherent difficulties like slow growth rate, low volumetric yield, difficulty in controlling stability, low yield as compared to microbial sources, the PTC is far from becoming an economically viable source for the production of flavours in food industry (Harlander, 1994).

Conclusions

From the foregoing account, it can be concluded that as the trend towards natural foods is increasing, more and more newer biotechnological processes will be employed for the production of natural food additives. Flavour is one such area where extensive research needs to be further done.

However, the main limitation is with regard to the safety and stability of the flavour in the food system, which is very important for the overall quality and acceptance of the product. The development of novel and cheap production processes, such as solid-state fermentation may help to overcome some of the current limitations of microbial flavour production and also widen the spectrum of bioproduction of such compounds.

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Nutritive Sweeteners from Starch

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Introduction

The discovery that starch could be transformed to sweeter substances by heating with dilute acid was made nearly two centuries ago by G.S.C. Kirchoff, a Russian scientist. The discovery earned him a lifetime annual pension of 5000 roubles and the Order of St. Anne from the Russian Emperor. Subsequently, an other scientist showed that starch was a polymer of glucose and that it could be hydrolysed to glucose. This has been the foundation on which the nutritive starch-derived sweetener industry is based.

Kirchoff recognised the commercial potential of his discovery and continued work on developing a sweet product. He was able to prepare a syrup that crystallised upon standing and from which, a solid product was obtained by pressing the mass in cloth sacks. The material was impure, but considerable efforts went into commercialising the process.

This discovery came at the height of the Napoleonic wars, when the British blockade of European ports resulted in an acute shortage of sugar (coming in from the West Indies). The process was commercialised and a number of plants, mainly based on potato starch, were built in western and central Europe. However, with end of the Napoleonic wars, inter-

est in the process waned.

The process spread to the United States, where an industry based on maize (corn) starch was quickly developed. The development in the USA was much more rapid than in Europe. Starch hydrolysis was first practised in the United States in 1842 and in 1886, the country had its first facility producing sweeteners. And since that time, the corn sweetener industry has grown tremendously. A variety of starch-

Starch-based sweeteners are the major product category of the starch industry, irrespective of the source of starch.

based sweeteners were developed over the years, both syrups and solids.

Starting with acid hydrolysates of starch, the industry moved on to enzymatic hydrolysates (with the availability of various types of enzymes in commercial quantities at affordable prices). Today, while acid hydrolysed glucose syrup is still produced in large quantities, all

the dextrose and substantial quantities of high DE syrups are produced after enzymatic conversion. Also, glucose syrups having various sugar profiles are available today, produced with different types of enzymes. However, the product that has had the greatest impact on the starch sweetener, was the commercial development of high fructose syrup. For the first time, a starch-derived syrup was available, which was as sweet as sucrose.

Starch-based sweeteners are the major product category of the starch industry, irrespective of the source of starch. However, largest quantity of starch sweeteners is derived from maize, as the maize refining industry is the largest producer of starch. The United States, the world's largest producer of maize, is also the largest producer of starch-derived sweeteners. Maize sweetener production alone accounted for demand of more than 17.8 billion MT of maize in 1995. Of the more than 23.2 million MT of products produced from maize wet milling in 1995, nearly 13.6 million MT were sweeteners, accounting for about 54% of the entire U.S. consumption of all sweeteners. These products include high fructose syrup (HFS), glucose syrup, dextrose, corn syrup solids, and maltodextrins. The 1995 levels represented a 30% increase over the previous ten years and a 55%

Nutritive Sweeteners from Starch

Table 1. U.S. Wet Milled Use of Field Maize (Crop Year September/August)

Description	1990/91	1991/92	1992/93	1993/94	1994/95	Million MT
						1995/96
HFS	10.31	10.67	11.27	12.03	10.30	10.63
Glucose syrup and dextrose	5.44	5.72	5.85	6.07	5.10	5.21
Total maize sweetener	15.75	16.39	17.12	18.10	15.40	15.84
Maize starch	6.31	6.46	6.48	6.64	5.54	5.65
Total wet milling	22.07	22.83	23.60	24.74	20.94	21.49
US maize crop	215.93	203.44	257.92	172.44	223.80	175.02
						Per cent
Maize sweetener share	7.30	8.05	6.63	10.50	6.88	9.05
Wet milling share	10.22	11.22	9.15	14.35	9.35	12.28

* Total wet milling includes estimated use of maize for sweetener and starch output-does not include estimates for maize wet-milled for fuel ethanol

** Values for 1995-96 are forecasts

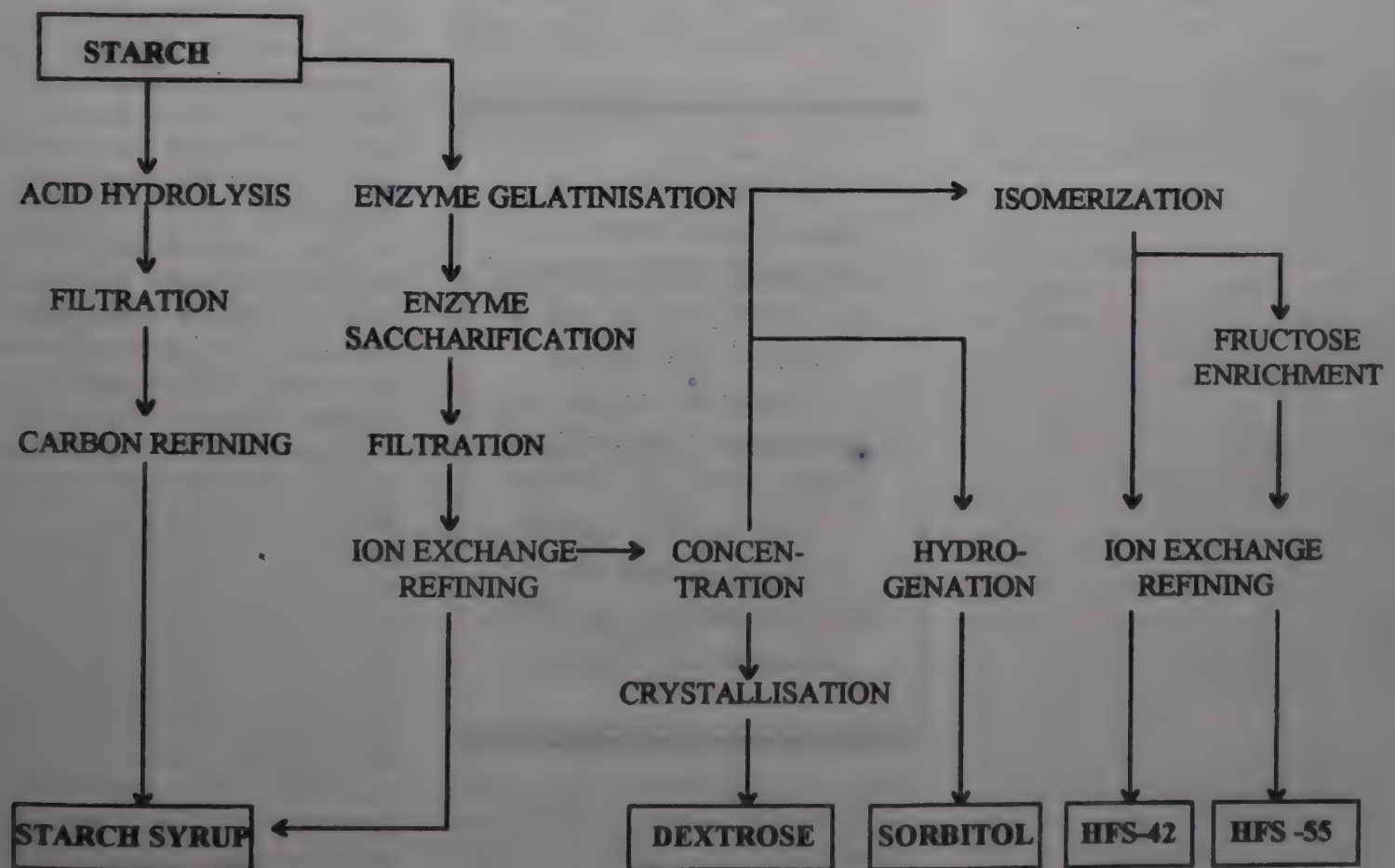


Fig 1 : Manufacture of starch derived nutritive sweeteners

Table 2. Sweetness of Starch-Derived Nutritive Sweeteners

Saccharide	Relative Sweetness
Sucrose	100
Glucose syrup, 25DE	20
Glucose syrup, 43 DE	40
Glucose syrup, 63DE	60
Dextrose	75
Maltose	45
Sorbitol	63
Maltitol	90

over 1980. In the United States, 14.2% of the maize crop is used by refiners; of this, 7% was used in the manufacture of sweeteners (Urbanic, 1996). Table 1 presents data on the disposal of maize grown in the United States (United States Department of Agriculture, 1995).

Types of Sweeteners Produced from Starch

Starch-based sweeteners can be either partial or complete hydrolysates, the catalyst used for hydrolysis being either acid or enzymes. The hydrolysates, both partial or complete, may be hydrogenated to give a mixture of or pure polyhydric alcohols having different functionalities. The starch used can be derived from various botanical sources with no impact on the properties of the syrup. However, the purity of the starch used does have an effect on the ease of the manufacturing process and could have an impact on certain properties of the syrup such as colour and taste. Fig 1 is a schematic representation of the manufacture of starch nutritive sweeteners. Details of manufacturing process have been described by Schenck and Habeda (1992).

The relative sweetness of some of the starch-based

sweeteners is given in Table 2 (Tekchandani and Dias, 1998).

The traditional analytical tool to measure the extent of conversion of a starch-derived sweetener is Dextrose Equivalent (DE), which is the % reducing value, expressed as dextrose, on a dry substance basis. Thus, pure

The traditional analytical tool to measure the extent of conversion of a starch-derived sweetener is Dextrose Equivalent (DE), which is the % reducing value, expressed as dextrose, on a dry substance basis.

dextrose would have a DE of 100; unmodified starch, also a value approaching zero. However, convenient methods like HPLC to measure the sugar profiles of a substance are now available. The measurement of DE is losing its value specially since it is possible to have syrups with different com-

positions but having the same DE. Thus, DE has value only, when the procedure of manufacture is specified and today, is commonly used only with the acid hydrolysed syrups.

Commercial Products

Acid Converted Syrups (Glucose Syrups)

This is the traditional glucose syrup and is the most popular of the starch-derived sweeteners. Products generally have a DE, ranging from 30 to 47, with the most common being products with a DE of 39-40, generally referred to as confectioners syrup. Nearly all the syrups produced in India, at present, fall in this group. The Prevention of Food Adulteration Act (India) does not have a specification for glucose syrup other than specifying that the syrup should have a sulphur dioxide concentration of less than 450 ppm. Dried glucose syrup, having a sulphur concentration of greater than 40 ppm, has to be labelled so that it is meant for use in sugar confectionery only. Some customers specify the amount of sulphur dioxide acceptable, with customers in pharmaceutical industry requiring a product with no sulphur dioxide. The solids level in the syrup is also customer specific. In India, glucose syrup is normally marketed in steel barrels, generally has 83 to 85% solids, which make the product extremely viscous. Material sold in tank cars, has a lower solids level to facilitate pumping. In the United States and Europe, where most of the material is sold in tank cars, the solids level is usually 80%, except for some quantities sold to chewing manufacturers, which have 85% solids. Today, there is a shift to supply lower solids level syrups to chewing gum manufacturers also, who have their own facilities for concentrating to desired levels.

Table 3. Typical Carbohydrate Profile of Some Glucose Syrups

	Low DE	Regular DE	High DE	High Maltose
DE, %	30	43	63	43
Dextrose (DPI)	9	14	37	6
Maltose (DP2)	10	14	31	44
Trisaccharides (DP3)	12	12	11	13
Tetrasaccharides (DP5)	9	10	5	3
Pentasaccharides (DP6)	9	8	4	2
Greater than DP6	51	36	11	32

Note : The low and medium DE syrups are produced by acid hydrolysis of starch. They can also be produced enzymatically in which case, the sugar profile will be different. The high DE syrup is produced by hydrolysis with acid followed by amyloglucosidase. The high maltose syrup is produced by hydrolysis with *Bacillus* alpha-amylase followed by fungal alphaamylase.

Applications

Glucose Syrups

The various types of syrups, whether produced by acid catalysis, enzymes, or a combination of both, will be considered together. Syrups produced by the different processes are used to produce a particular product, though the syrup composition impacts on the quality of the product. It is impossible to list all the applications in which glucose syrups are used. Only the major applications are indicated below.

A major use of glucose syrup is in hard-boiled sugar confectionery. Acid hydrolysed syrups are the most commonly used, though syrups produced using enzymes are gaining acceptance, especially in the manufacture of deposited candy of superior quality. In this application, sweetness is not an important consideration. Rather the control of sugar crystallisation (doctoring agent) is the prime reason for such use. High-boiled confectionery are a classic example of a product in a "glassy" state. In appearance, they are solid, but actually they are su-

percooled non-crystalline liquids, which are so far below their melting or softening point that they have assumed solid properties without crystallising. For crystallisation to occur, there must be a "nucleus" to act as a seed. The nuclei are formed, when the supersaturation is sufficiently high, but

Acid converted glucose syrups have traditionally been used in gums and jellies to give protection against the crystallisation of sucrose.

the higher the viscosity the slower the rate at which they form. Molecules of the crystallising substance have to migrate to the nuclei, which is severely limited, when the viscosity is extremely high. To obtain a satisfactory high-boiled sweet, a solids level of

96% has to be achieved. If the confection contained sugar alone the system would be unstable. This problem is overcome by adding 35-40% liquid glucose, when using open pan boiling, 35 to 50% for vacuum-cooking and 40 to 60% for deposited candy. The viscosity of the syrup reduces hinderance of crystallisation.

The ERH (Relative Vapour Pressure) of high-boiled candy is about 30%. As the atmospheric humidity is nearly always above this, there is a tendency for the sweet to absorb moisture. This reduces the solids concentration, which results in crystallisation (graining) of sucrose. The presence of glucose syrup imparts a skin to the surface, which prevents the migration of moisture to the interior of the sweet.

The all-enzyme produced maltose syrups presented to the hard-boiled confectioner an alternative to the acid or acid-enzyme syrups, which were low in glucose and had lower viscosities. This resulted in a high-boiled candy mass with a lower viscosity, permitting better deposition performance and lower air entrapment. Candy produced with high

maltose syrup have an improved gloss and better finished appearance. The low glucose content decreases the tendency to brown colour formation.

In fondants and certain other types of confections, some degree of graining is necessary and in such instances, lower concentrations of glucose syrups are used.

In the manufacture of toffees and caramels, the characteristic flavour and colour are formed due to the Maillard reaction between the reducing sugars and the milk proteins. As a rule, therefore, acid converted syrups, with a high glucose concentration, are preferred. If a high maltose syrup is used, the product has a lighter colour. This gives the product a creamy appearance, which may be desirable at times.

Acid-converted glucose syrups have traditionally been used in gums and jellies to give protection against the crystallisation of sucrose. Such candies are low-boiled to a moisture level of about 20%. In recent years, especially in Europe, there has been a shift to high-maltose syrup, which results in less stickiness and a cleaner gel performance. The use of high-maltose syrup results in a more tender candy, specially when pectin is used as the gelling hydrocolloid.

Chewing gum consists of sugars impregnated into a gum base. Typically, acid-converted glucose syrups (35 or 42 DE) contribute about 25% of the sugar. The higher sugars in the syrup contribute to the texture of the gum. The only significant factor that contrasts syrups used for gum manufacture is the higher solids concentration (85%), as the gum manufacturing process is not a boiling process and any water addition has to be minimised. In the Indian context, a considerable quantity of the syrup, packed in barrels is normally marketed at 85% solids.

Glucose syrups are also used, in a number of areas, in the

manufacture of flour confectionery. For example, in fermented products, they can be used as a source of fermentable sugars as well texture improvers. The reducing sugars enhance the browning reaction for crusts. High DE glucose syrups impart humectancy to cakes, thereby increasing shelf-life. In some instances-glucose can replace about 15% of the sucrose.

Large quantities of glucose syrup are used in Europe and in the United States in the manufacture of fruit preserves (jams). Even in the limited amount of jams produced in India, not much liquid glucose is used. The addition of

better, high maltose syrup are used. When preserves with a high solids (76%) are desired, as those used in baking, it is necessary to use higher levels of 63 DE glucose syrup.

Glucose syrups can be used in frozen desserts and ice cream as reported by Tekchandani and Dias (1998). The amount of glucose syrup used in India is much lower than what would be used in the United States for the same amount of production. Possibly, the price of glucose syrup *vis-a-vis* the price of sugar is a constraint. Manufacturers, unfortunately, do not consider the benefits to be gained, when using starch-based syrups.

Another significant use of glucose syrup in the United States and Great Britain is in the manufacture of ketchup. The function of the syrup is to control sweetness and to give body and texture to the product. Glucose syrup 63 DE is normally used in the United States and often replaces all the sucrose. In India, the description of "Tomato sauce", "Tomato ketchup", and "Tomato relish" in the Prevention of Food Adulteration Act, 1954, does not permit the use of glucose syrup or any other corn derived sweetener. Only sugar is permitted.

Glucose syrups (not including HFS) have limited use in soft drinks. However, in soft drinks, where sucrose is replaced with high intensity sweeteners, glucose syrups are added to give body and mouthfeel to the product. A growing application of glucose syrups is in drinks, intended to provide nutrition via high levels of soluble carbohydrates, often used by sports-persons or by convalescents (Shi, *et al.*, 1995). As these syrups, unlike sucrose, do not invert under acidic conditions, there is no change in osmolarity with time. Glucose syrups have physiological benefits over dextrose and sucrose. Sucrose, because of its fructose component, does not yield all its energy potential as quickly as dextrose or glucose syrup. Glucose syrups are also more

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glucose syrup is to prevent the crystallisation of sucrose. Traditionally, this was achieved by inverting part of the sucrose. This minimised the danger of crystallisation to some extent, but it made the product excessively sweet. The latter tends to mask the fruit flavour. The most commonly used syrup is an acid-enzyme 63DE glucose syrup. The higher osmotic pressure of such syrups also improves the microbiological stability of the syrup. In the case of preserves made for biscuit fillings, where low methoxy pectins (and calcium) are used, 42 DE acid syrups, or

palatable than dextrose. This is because the lower sweetness and lower osmotic pressure of the syrup does not give a feeling of nausea. Quicker gastric clearance, due to the lower osmotic pressure, possibly plays a significant role in their greater acceptability. There is a considerable market for such drinks, both carbonated and otherwise, in the United States and in the United Kingdom. Mixtures of 42 DE acid syrup and 63 acid enzyme syrup, to give an average DE of 55 are used at a concentration of 5-10%.

Glucose syrups are also used in the manufacture of non-dairy creamers, breakfast cereals and in many types of confections other than those mentioned above. These syrups are also used in liquid medicinal formulations. Here, they are used as carriers for active ingredients that are not palatable. The other reason for the use of these syrups, especially in cough mixtures, is that the viscosity that they impart, permits slow release in the mouth and throat. At the concentrations needed to prevent microbial deterioration, sucrose would possibly crystallise. Acid-converted 42 DE syrup is normally used.

Glucose syrups are used extensively in brewing. In this application, the sugars are used as a fermentation substrate for the yeast, rather than as an ingredient of the final product. Some amounts of glucose syrups are used in the manufacture of liqueurs, where they impart sweetness and viscosity. High maltose syrups are generally used for the purpose.

Acid-enzyme Syrups

Using acid alone, it is difficult to produce palatable syrups with a DE higher than 50. To produce such syrups, the starch is first treated with acid, which is followed by the treatment with enzyme. Depending on the type of enzyme used, the sugar profile of the product can vary. However,

this process usually uses a glucoamylase and the DE is controlled to about 60 to 70. Such syrups are extensively used in fruit products and in some types of confectionery. In the United States,

Dextrose is available commercially either in the crystalline form as either the monohydrate or in the anhydrous form. It is also available in solution.

very large volumes of acid-enzyme syrups are used as adjuncts by the brewing industry. A typical Carbohydrate profile of some glucose syrups is given in Table 3.

Enzyme-enzyme Syrups

This type of syrup is extensively produced in Europe and is rapidly replacing acid-acid and acid-enzyme syrups. In Europe

Dextrose, being a monosaccharide, exerts a greater osmotic pressure than sucrose, which gives it a better preserving action against bacterial contamination.

and Japan, the dual enzyme process is most developed for the manufacture of high maltose syrups, which are used in confectionery or hydrogenated to produce maltitol containing syrups. In Latin America and

Canada, these syrups are used extensively as adjuncts in brewing. In fact, the rapid growth of the maize starch industry in Brazil is due to the large quantities of such syrups required by brewers.

The replacement of random acid catalysis by specific enzyme catalysts permits greater control over the composition of the syrup produced. Using different enzymes, it is possible to produce a variety of syrups. For example, it is possible to produce syrups with maltose concentrations ranging from 50 to 90%. Thermostable alpha-amylases derived from either *Bacillus licheniformis* or *Bacillus stearothermophilus* are used, in the liquefaction (thinning) state. In a typical process, the starch slurry adjusted to a pH of 6.0-6.3, containing enzyme is heated in a jet cooker at 106-108 °C and held for about an hour to achieve a DE of about 12. The hydrolysate is cooled to 60°C, the pH adjusted to the optimal for the enzyme being used, and then treated with the specific enzyme desired. Several enzyme combinations can be used to give a variety of commercial products. (Table 3)

Dextrose : Crystalline and Liquid Products

Preparation

Dextrose is the name commonly used in industry for D-glucose. Dextrose is available commercially either in the crystalline form as either the monohydrate or in the anhydrous form. It is also available in solution, and is generally not referred to as glucose syrup but, as liquid dextrose. Today most, if not all, of the dextrose manufactured is produced by enzyme-enzyme hydrolysis of starch. Under suitable conditions, the glucose concentration in the hydrolysate can be as high as 96%. After adequate purification with ion-exchange resins and activated carbon, the saccharified starch is

concentrated and taken for crystallisation. Whether one gets the monohydrate or the anhydrous depends on the conditions of crystallisation.

The liquid dextrose is prepared either by dissolving crystalline dextrose (melting) or by subjecting the saccharified and purified starch hydrolysate to "chromatographic separation" using resins. This results in a solution of glucose, which is marketed after concentration. The purity of the solution can be adjusted by varying the parameters, employed during chromatography (Shioda, 1992). Alternatively, the mother liquor after the crystallisation of dextrose can be subjected to "chromatographic separation" to increase the glucose concentration.

Applications

Dextrose used for food applications is available either as the crystalline monohydrate or as a solution. Anhydrous dextrose is used to a small extent in foods mainly as a carrier for intense sweeteners and other such products in those cases, where the monohydrate cannot be used due to moisture absorption.

Dextrose is more than an alternate sweetener, for it has several unique functionalities. Dextrose is 75% as sweet as sucrose. However, the presence of other sugars, flavours, acidity, etc. influence this ratio. For example, in a high sweetener formulation with low acidity, dextrose, when substituted for sugar at 40%, has a relative sweetness of 90%. As dextrose has the highest heat of solution (latent heat of crystallisation) of the common sugars, there is a distinct cooling feeling in the mouth, when eating dextrose monohydrate. This distinctly increases the appeal of fillings and icings. Dextrose, being a monosaccharide, exerts a greater osmotic pressure than sucrose, which gives it a better preserving action against bacterial contamination. However, in many applications, dextrose can

be used as a partial replacement for sucrose. In such instances, the price of dextrose *vis-a-vis* sucrose would be the deciding factor. In India, dextrose is priced higher than sucrose.

Dextrose is used in toffees and caramels, where it enhances colour formation coupled with increased flavour. In compound formulations, the viscosity of the toffee in the dipping pots is stabilised, thereby reducing waste. Not more than 10% of the weight of the sucrose should be used. Powdered fillings for hard boils may be formulated with dextrose as the sole sweetener. Because dextrose dissolves instantly, it gives the impression of a liquid centre with a cooling effect on the tongue. Dextrose, unlike sucrose, can be direct by compressed into tablets without the need for granulation. When used together with sucrose, dextrose is blended with the standard granulation mix. Dextrose can replace upto 10% of the sugar in sugar coated gum. It can also be added to the gum formulation where it enhances the gum's flavour, while balancing the overall sweetness. Dextrose is used extensively as a dilute and bulking agent for food powders, non-nutritive sweeteners, colourants, spice extracts, etc. There are many advantages to use dextrose in biscuit manufacture. It can be used in wire cutting, depository, sheeting and rotary moulding processes. In cookies made by wire cutting and depositing, 5-25% of the sugar can be replaced by dextrose. For cookies made by sheeting and cutting, upto 50% of the sugar can be replaced by dextrose. In these kinds of cookies, dextrose controls spread and gives the finished product a more uniform surface colour. In rotary moulded cookies, dextrose can replace at least 30% of the sucrose. Dextrose provides the ideal properties needed to control spread during baking. It also prevents tailing of the surface colour. Dextrose, upto a 50% replacement for sucrose, can also be

used in formulating dry icing mixes, as well as prepared mixes. Dextrose provides a smooth texture and mild sweetness.

In India, by far the largest food application for dextrose is as an "energy" drink. The perception of dextrose as a source of instant energy is extremely strong. Dextrose monohydrate is fortified with calcium and vitamin D and is marketed as a pick-me-up to be taken after dilution with water. Flavoured products are also available in which about half the dextrose is replaced by sucrose. Sales volume of flavoured products are much lower than the unflavoured products possibly due to the strong linkage of dextrose as a medicine, rather than a cold drink. There is scope for improving the formulations available at present. The strong "energy" perception, together with a product with a better mouth feel will help in increasing volumes of such products. In the United States and Europe, such drinks are marketed in the sports drink category.

In Indonesia, like India, such drinks are really appropriate for the climate, because, one gets hot and perspires no matter what one is doing! It is interesting to note that a single such product (Gatorade) has world wide sales of US\$ 1.3 billion. International volume grew 51%, including 69% growth in Latin America and the Pacific, and 12% growth in Europe. The European market for energy drinks grew from 4 million litres in 1991 to 78 million litres in 1995 (Anon 1996). There is tremendous scope for the growth of this sector in India.

High Fructose Syrup (HFS)

Preparation/Production

In the United States, HFS is produced only from corn starch, hence the name 'High Fructose Corn Syrup' (HFCS). The high glucose syrup produced for the manufacture of dextrose is

Table 4. United States Use of HFS in 1995 in Foods and Beverages

	MT(000)	Market share %
Beverage use		
HFS55	1946	55.7
HFS42	579	16.6
Total beverage use	2525	72.3
Food use		
HFS55	149	4.3
HFS42	819	23.4
Total food use	968	27.7
Total food/beverage use	3492	100.0

isomerized with the microbial enzyme, glucose isomerase, in an immobilised form. The use of immobilised isomerase represents the first large scale use of immobilised enzyme. The syrup after isomerization contains about 42% fructose. Using chromatographic separation, a syrup with 90% fructose is produced, which is then diluted back to 55%, the dominant commercial product. Some amounts of 90% HFS are used to manufacture crystalline fructose.

The production HFS in the United States during 1997 is projected to rise to 8.5 million MT, dry basis, up from 8.2 million MT in 1996. HFCS-55 production is forecast at 5.4 million MT and HFCS-42 at 3.1 million. In 1975, U.S. per capita consumption of fructose syrup stood at 2.3 kg. In 1996, the number was 27.3! To enable U.S. consumers to use 27.3 kg of HFCS apiece, maize refiners bought about 12.7 million MT of maize. That is, 1.6 million hectares of maize had to be harvested for this application.

Applications

HFS 55, which is the syrup produced in larger quantities, is mainly used in the manufacture of

beverages as a replacement for sugar. It should be noted that when used as a sugar replacement the price of HFS should be compared to that of refined sugar syrup. A greater part of HFS42 is in foods, though unlike HFS55, significant quantities are used in beverages. The 1995 data of the use of HFS in

In India, sorbitol is permitted for use as an emulsifier and stabiliser, and as a sweetening agent in certain confections.

foods and beverages in the United States is given in Table 4.

HFS is not produced in India, the reason for this being that the differential between the price of sugar and starch is not great enough to absorb the cost of converting starch to HFS. However, indications are that it may be a feasible proposition in the future. Though the per capita sugar consumption is not the highest, India

(together with the EU) is the world's largest sugar consumer, the estimated consumption being 14.6 million MT (HRA Market Research & Analysis (USA) Personal communication 1997). At the same time it is one of the lowest consumers of soft drinks. As an indicator, Indians consume three 236 ml servings of Coca-Cola Co's carbonated soft drinks. Egypt consumes 27, Kenya 29, Brazil 131, and USA 363 (The Coca-Cola Company (USA), 1996 Annual Report). Considering the climatic conditions, as well as the increased disposable incomes and changing life styles in India, it is probable that soft drink consumption will increase. We visualise a situation where sugar may be in short supply, and the manufacture of HFS would become a necessity. The yields of maize (from which starch is manufactured) in India is about 1.5 MT per hectare, as compared to about 8 MT per hectare for the USA and Europe. Thus, there is scope to increase production of maize without increasing the area under maize to meet the increased demand for starch.

Sorbitol, Maltitol and Hydrogenated Glucose Syrup

The hydrogenation of glucose solution in the presence of Raney catalyst results in the formation sorbitol. This, after purification, is marketed as a 70% solution, or is crystallised to give a solid product. The hydrogenation of high maltose syrups results in a mixture of polyhydric alcohols rich in maltitol, the concentration of maltitol depending on the concentration of maltose in the hydrolysate. Maltitol syrups with maltitol concentrations, ranging from 50-55% (*Lycasin*) to 85% and higher are available commercially. Solid maltitol is also available. (Le Bot and Gouy, 1995).

Applications

The use of polyhydric alcohols in foods, including their legal status in India has been recently described (Kacchi, *et al.*, 1998). In India, sorbitol is permitted for use as an emulsifier and stabiliser, and as a sweetening agent in certain confections. However, it is not included in the list of sweeteners in Prevention of Food Adulteration Act, 1955. None of the other polyhydric alcohols find mention. As the polyhydric alcohols occur in fruit and vegetables, which form part of our daily diet, the question of their safety is easily answered. Also, some of the polyhydric alcohols have been used in foods in the United States and elsewhere for several decades. Because polyols are functional food ingredients, their use is of interest in the design of reduced calorie foods as well as sugar-reduced or sugar free foods which are kind to the teeth. Such sugar-

free confections are common in the mass confectionery markets in the United States and Europe. In Denmark Norway, and Finland, for example, sugar-free gums represent over 90% of the polyol market.

As stated by, Kachhi, *et al.*, (1998) there are market opportunities in India for such reduced sugar, reduced calorie, tooth friendly products targeted at the growing number of health-conscious individuals.

Conclusion

The use of the starch-derived sweeteners described above is often based on properties other than their sweetness. This is particularly true of acid hydrolysed confectioners syrups. In other instances, such as HFS, sweetness is the main consideration and HFS is used mainly as a replacement for sugar. In some cases, for example, maltitol and sorbitol, both sweetness and other attributes, physical and physiological, dictate their use in a food. (Storey and Zumbe, 1995). In the Indian context, it may be difficult to replace sucrose with sweeteners derived from starch unless their use results in improved product characteristics. Starch derived-sweeteners, at present, are priced higher than sucrose. However, with the increased demand for sucrose, as well as the increased requirement for sweeteners, starch sweeteners may become viable alternatives. It should be remembered that sucrose cannot be replaced by starch sweeteners in all applications.

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Sealers India manufactures portable auto sealer which can seal all types of thermoplastic films like LDPE, HDPE, HMHDPE, PP, PVC and films below 0.2mm thickness, polyethylene laminated papers, foil and polyester. Applications include bags for food, confectionery, powders, cakes, candies, seeds, grains, sweet and wet substances; packaging for mechanical parts, screws bolts, tools, electronic and electrical components and toys, sterilised pouch for medical instruments, pathological samples, sanitary packaging, packaging of medicine and drugs. In use, keep the bag on the sealing jaw, press the pedal switch. The jaw closes automatically sealing the bag tightly. After a predetermined time, the jaw opens. The sealing and cooling time can be adjusted. The jaw dwell time can also be adjusted. The machine can be operated either on manual mode by operating the footswitch or on auto mode. The machine can seal 900 pouches/hour depending on the model and the packaging material.

For more details write to :

Sealers India
B-15 Annexe Mugappair Indl
Estate (West)
Behind Wavin India,
Chennai - 600 050

NEW PRODUCTS

Two-layered Cake

The joint venture company, Godrej Pillsbury Ltd., has recently launched a range of world famous Pillsbury Cake Mixes in key Indian cities. Available in six flavours-chocolate, lemon, banana, carrot, white and brownie-these cake mixes will make the entire process of baking cakes at home very simple.

The company will leverage the marketing and technical expertise of its overseas partner, The Pillsbury Co, and its own distribution strength to establish its product range amongst the discerning Indian consumers.

Corny Treats

Following the launch of its Pillsbury Cake Mixes, comes Green Giant Corn from the stable of Godrej Pillsbury Ltd.- world's No. 1 sweet corn from the world's largest vegetable brand.

Imported from the US, available in two varieties-Niblets & Cream Style Sweet Corn, the brand comes in an easy-to-open flip-top can. Niblets Sweet Corn is specially vacuum-packed with minimum water so that it stays golden, fresh and crisp. Cream Style is quick-cooked in its own sweet cream. Niblets' 198 gms is available for Rs 33, 312 gms for Rs 48.50, and Cream Style's 418 gms for Rs 50.

Nutty Mix

Country club, a premier brand of Phil Foods, a division Phil

Corporation Ltd. has launched a combination of mixed nut, "Nutty Mix". This hygienically processed pack contains peanuts, grams, cashew kernels and peas seasoned with herbs and spices.

Country Club Nutty Mix is targetted at people who love snacks with a spicy and tangy flavour. The product is processed and packed in Phil Corp.' Goa factory. Nutty Mix is available in two attractive packs of 40 gms and 80 gms at Rs. 8 and Rs. 15 respectively.

Water Purifier

Ion Exchange India Ltd, the maker of Zero-B, has launched a 20-litre Puripack in response to the recently-published Consumer Education and Research Society survey. The survey observed that 10 to 13 brands of bottled water are not safe and do not conform to WHO standards.

The Zero-B Puripack is delivered and replenished at the customer's doorstep, providing pure drinking water 24 hours a day, while eliminating maintenance hassles. The Puripack is priced at Rs 60 a bottle and comes in a range of attractive dispensing systems to match office decor. Dispenser prices range from Rs 320 to Rs 10,500.

New Cheese Spread

On the heels of its entry into the dairy products category, Britannia Industries Ltd. recently launched its cheese spread across the country.

Available in plain, jeera, chilli capsicum and black pepper flavours, the spreads are made from real cow's milk and contain actual pieces of the flavouring ingredient, claims the company.

The cheese spread is targeted at the family - as a fun-filled spread for children and a healthy nutrient for adults. Packaged in 200 gm glass bottles fitted with tamper proof 'pop-up' lug caps' and 'neck sleeves', the product is priced at Rs 30 per bottle.

New Ranges of Mozzarella, Cheddar Cheeses from Amul

Amul has launched a wide range of exotic cheese. The range includes the Swiss Emmenthal, Italian soft Mozzarella and slices of processed cheddar cheese.

These are in a ready-to-eat shape and are available in a pack of ten slices, each weighing 20 gms in attractive plastic wrappers. This new offering from Amul is expected to revolutionise the market for cheese in India". The cheese is being manufactured at the new state-of-the art plant, set up by the Kaira District Co-operative Milk Producer's Union Ltd. Anand, at Khatraj near Ahmedabad.

Amul will be the first company in India to make these specialised foreign cheeses in India on these scales. Mozzarella cheese is used as a topping in authentic Italian pizzas. Cheddar is among the most popular cheeses in the European countries.

RESEARCH ROUND-UP

Almonds To Reduce Sugar Levels

Almonds, relished since times immemorial as dry fruits and for their health benefits, have been reported to lower blood sugar levels, a finding that may bring cheer to diabetics. Sweet almonds are used as tonic for intestines, brain, liver and the chest, while bitter almonds are used in inflammation, headache, weakness of eyes and bronchitis. Recently, scientists at the Indian Institute of Technology (IIT), New Delhi, found that almond seeds lowered blood sugar levels by about 28 per cent at the end of two months in experimental rabbits. The factor responsible seems to be a non-oil fraction, a report by IIT scientists Sunita Teotia and Man Singh in the Indian Journal of Experimental Biology. The scientists studied the effect of entire almonds, the defatted seeds as well as its oil on blood sugar levels in rabbits. Almond seeds reduced blood sugar levels significantly by 28 per cent at the end of the two month study.

The hypoglycemic effect was lower in defatted seeds and least in the oil portion as reported in the journal. The active principle may be a substance other than the oil of almond, which is partly soluble in diethyl ether. More studies need to be conducted to isolate the factor that reduces blood sugar levels.

Anti-adulteration Milk Kit

For those who worry about the quality of the milk consumed,

help might soon be at hand in the form of an easy-to-use adulteration detection kit.

Scientists at the National Chemical Laboratories (NCL) in Pune have developed a technique to detect synthetic milk, popularly known as milk adulterated with synthetics such as urea or detergent.

A team of scientists at NCL., headed by Dr. S.S. Kulkarni and Dr. A.M. Bodhe, have succeeded in identifying the reagents that can detect synthetic substances in milk. The NCL team recently demonstrated the adulteration detecting kit to a gathering of representatives from the dairy industry and received a favourable response to their product. The dairy industry, especially in Mumbai, has been plagued with the problem of adulteration by suppliers. The kit essentially consists of two chemicals and a standard colour chart. To detect adulteration, a consumer must add a pinch each of the chemicals to the milk, wait for five minutes and then compare the changed colour of the milk with the chart.

Target users for the kit would primarily be the dairy industry, which can use it to detect the adulteration by suppliers. The kits can also be used by individual households.

New Vaccine for Immunising Fish

The Fish pathology Laboratory, Department of Aquaculture of the College of

Fisheries in Mangalore has made a breakthrough in protecting fish against disease. The new vaccine - "Bacterial Biofilm" - with Glycocalyx, which acts as a natural casing against the loss of antigens in large varieties such as carps, has been introduced for oral immunisation in fish.

The new vaccine has been found to be effective, according to Dr. S.L. Shanbhogue, Director of Instruction of the Fisheries College. This was developed by Dr. K.M. Shankar and his team with funding support from the International Foundation of Science, Sweden.

CMFRI Develops Multicrop Sea Farming

The Vizhinjam Research Centre of Central Marine Fisheries Research Institute (CMFRI) has developed a new farming procedure for multicrop system to cultivate pearls, mussels, finfishes, shellfishes and other organisms in shallow sea bottom using special cages. This technology, developed for the first time in the country, will help in promoting marine farming in all the shallow areas of Indian seas, including the lagoons of Lakshadweep and Andaman Islands, with minimum investments.

These special cages could be operated from canoes, catamarans or boats using marker buoys and anchor ropes. With an investment of Rs 20,000 for the cost of the cage, it would be possible to generate an income of Rs 50,000 for the farmer by adopting this technology.

DATA BANK

India's Export of Non-Basmati Rice From Kandla Port - 1997

Country	Quantity : MT											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
S. Arabia	27341	16228	20337	11467	8694	1621	6986	1145	1656	2983	8337	19062
Russia	8432	40963	21580	24242	2115	8127	11553	13833	1003	4531	593	14488
S. Africa	4553	10866	24979	15026	19297	2900	7711	29518	0	12527	22919	200
Sri Lanka	23358	0	0	0	0	0	0	0	0	1142	38167	24500
Somalia	3011	13438	0	6192	0	2264	1706	0	0	0	0	0
Australia	14706	0	0	0	0	0	0	0	0	0	0	0
U.A.E.	2283	2763	6599	2179	4120	3099	1668	753	2125	3318	3412	3638
Mauritius	11365	0	0	0	0	0	0	0	0	0	0	11365
Kuwait	450	742	1549	257	147	282	237	1338	613	1117	703	7366
Nigeria	6531	0	0	0	10051	8802	0	29064	0	0	7033	0
Senegal	0	5068	0	0	6014	0	8933	0	0	0	0	14033
Kenya	3867	0	20	0	0	0	0	0	150	0	0	0
U.S.A.	0	1694	1931	42	0	0	0	15597	105	441	163	10099
Poland	2304	0	0	0	0	0	0	0	0	0	0	0
Yemen	0	0	1873	0	0	0	0	1975	0	2832	222	0
Bahrain	85	593	594	298	1072	148	301	148	447	192	232	317
Jordan	171	586	105	40	11542	912	0	0	101	7493	0	0
Iran	703	0	106	10847	0	0	0	19782	0	0	0	0
Qatar	128	63	213	22	64	0	0	0	21	65	258	188
Tanzania	0	0	522	264	0	3496	0	0	44	0	0	0
Oman	0	67	0	0	21	0	0	0	0	0	0	0
Philippines	0	64	0	0	0	0	0	0	0	0	0	0
Israel	21	0	41	0	0	0	0	0	0	0	0	0
Lebanon	0	0	43	173	0	0	216	0	0	0	0	0
Cyprus	0	0	21	0	21	0	0	0	0	0	0	42
Germany	0	42	0	0	0	0	0	0	0	0	105	0
Belgium	21	0	21	0	0	21	21	0	21	21	21	0
Netherlands	21	0	0	0	0	0	21	0	0	0	0	0
	0	0	0	0	0	42						
Sweden	0	0	0	0	0	0	0	0	0	0	0	0
Greece	0	0	0	0	21	0	0	0	0	0	0	0
Others	296	212	275	296	656	8364	468	5350	5326	10419	295	169
Total	111677	93389	80988	71445	63877	40036	39821	118524	11612	45456	45849	101106

Source : Rice India, January 1998

TRADE FAIRS & GET-TOGETHERS

All Candy Expo-1998

The All Candy Expo-1998, will be held from June 22-25, 1998 at the Navy Pier in Chicago, Illinois, USA. The Chocolate Manufacturers Association and the National Confectioners Association of USA are the organizers of this Expo. The Expo is expected to have around 800 booths. The show floor will feature something new this year-the International Pavilion, where a broader array of confectionery products, will be on display. For information on exhibiting in the International Pavilion :- Contact Lorinda Heether or Libby Taylor or Susan Smith, National Confectioners Association of USA 7900, West Park Drive

Suite A-320, McLean, VA
22102-4203

Tel : 703/790-5011

Fax : 703/790-5752

E-mail : info @ candy usa org

Iba-98-Germany May 08th - 14th, 1998 at Dusseldorf in Germany

iba 1998 - The most comprehensive forum and the undisputed no.1 international trade event for baking trade will be held from May the 08th to 14th, 1998 at Dusseldorf in Germany. It is held on a three year cycle to meet with investment needs and to influence the multibillion market for

foodstuffs and confectionery across every continent.

iba'98 will present a wealth of information, biggest range of equipments and products for the entire baking industry. New developments in all areas of technology, shop design, the supply of raw materials, production and sales comprise the focus of this worldwide extravaganza. People, ideas and informations are what the visitors will find at iba'98 and in addition to an outstanding range of equipments for operation.

The seven iba days in May 1998 offers its visitors the core categories on display by exhibitors from all over the world, the best source of comprehensive informations on the world market and will include : * Baking Ovens & Accessories of all sizes and capacities * Bakery & Patisserie Machinery * Storage & Refrigeration Facilities * Baking Ingredients & Raw Materials * Energy - Systems * Management & Control Technology * Electronic Data Processing for Production, Sales and Supplies * Convenience Products * Shop - Fittings, Point - of - Sale Materials * Advertising & Packaging Materials.

Opportunity For Indian Visitors :

A special visit is arranged for Indian Businessmen, Technical Experts and Consultants. Further details can be obtained from The Indo-German Chamber of Commerce, Maker Tower 'E', 1st Floor, Cuffe Parade, Mumbai - 400 005 or The official tour promoters in India ORBIT - 1127 Midway Premises, A.S. Marathe Marg. Opp. Lucas TVS, Prabhadevi, Mumbai - 400 025. Fax No. : 22 - 430 5707, 431 4154.

E-mail : bom@
orbit.wiprobt.ems.vsnl.net.in

AOCS -OTAI International Conference & Exhibition on Oilseeds & Edible Oil Processing

The Oil Technologists' Association of India (OTAI) is organizing a joint International conference with the American Oil Chemists' Society (AOCS) of USA, from February 19-21, 1999 at Hotel Le- Meridien, Janpath, New Delhi, India. More than 800 delegates both from India and abroad are expected to attend the conference, where the technological progress made so far in vegetable oil processing and worldwide future prospects of oils and fats industry will be discussed at length.

For details Contact :

Dr S.C. Singhal,

Oil Technologists' Association of India.

1205, Nirmal Tower

26, Barakhamba Road,

New Delhi 110001.

Tel : 91-011-3315669, 3325365

AOCS Mailing Address :

P.O. Box : 3489

Champaign, IL 61826-3489

USA : Tel : 1-217-359-2344

Fax : 1-217-351-8091

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(24 - 27 November 1998 at Mysore)

Registration fee is being charged at the following rates :

Class of Registration	Regular	Late fee after 20th August 1998
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Non-Member (Indian)	Rs. 1200	Rs. 2000
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Full member	US \$ 450	US \$ 650
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Non-member	US \$ 500	US \$ 700
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